MANURING FOR HIGHER CROP PRODUCTION

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With kind regards

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MANURING FOR HIGHER CROP PRODUCTION

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MANURING FOR HIGHER CROP PRODUCTION

BY

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PREFACE

IN the following pages I have collected information about manures and soil management which will I hope prove helpful to farmers in drawing up their schemes for cropping. Conditions are changing so quickly, and labour and transport difficulties react in such complex ways, that no general advice could hold good all round. All farmers ought to increase the produce of their land, and most of them are trying to do so. I have aimed at giving them facts from which they can draw conclusions suited to their own conditions and bearing on their own problems. In agriculture the judgment of the man on the spot has usually to be final, and the more clearly he has the facts before him the sounder the judgment is likely to be. Fortunately the system of County Expert Advisers is in working order, so that no farmer need have any difficulty in getting information on which to base his plan of action.

E. J. R.

ROTHAMSTED EXPERIMENTAL STATION,
HARPENDEN.
January 1916.

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THE IMPROVEMENT OF THE SOIL

The productiveness of land may be increased in two ways: the soil may be better managed and the plant may be better fed. We shall deal with the first in this chapter and the second later on.

When left to itself soil has the awkward property of getting beaten down by the rain and then drying into hard clods or masses unsuited for plant growth. The farmer has to counteract this, and much of his time and a great deal of his money is spent in picking the soil up again and getting it once more into a proper tilth.

There are three useful means for bringing the soil into good condition: by cultivation, by chalking or liming, and by green manuring.

Cultivation.

The first object of cultivation is to obtain a good seed bed sufficiently compact to ensure close contact between the soil and the seeds or the rootlets, and yet sufficiently broken up to allow the roots to penetrate as far as necessary. Fortunately the subsoil needs less attention than the surface soil and for this reason it is often neglected. Once in every four or five years, however, it should be broken up either by ploughing to an extra depth or by means of a subsoiler following behind the plough. This can conveniently be done for the root or potato crops. The following results were obtained at Rothamsted with potatoes, each figure being the mean of five plots:

	tons	cwts	
Subsoiled	7	8	per acre.
Not subsoiled	6	18	,,
In favour of subsoiling	0	10	,,

The surface cultivation needs much more frequent attention. The work begins in the autumn and on medium or heavy land should start as early as possible. It is no exaggeration to say that much of the success of the management of the soil depends on getting the autumn cultivations well forward so that the ploughing is finished before the winter rain makes the land too wet for work. Late ploughing is costly and always liable to make bad work. Early cultivation, on the other hand, brings the soil into good condition for the autumn action of soil bacteria.

Everyone knows the good effects of fallowing land: how the weeds are killed, the tilth improved, and the plant enabled to make an unusually vigorous start. Dead fallows are nowadays out of the question, but a great deal can be done by getting the land broken up as early as possible and giving it a few weeks fallow. If the aftermath of the seeds lay is poor it may be advisable not to wait for autumn but to plough up in summer and give the land a bastard fallowing. When a second corn crop is to be taken the plough should follow the reaper as closely as possible.

This advice cannot always be carried out because of the shortage of labour at harvest time. The speed of the plough is only that of the farm horse. Steam ploughs work more quickly, but have not proved suitable for the three-hundred-acre farm. Motor ploughs are much more promising and if they come up to expectations they will solve much of the difficulty of early work. But whether it is to be done by a motor plough, a tractor, or a horse the great object must be to get the ploughing forward as early as possible.

Very wet land is only cultivated with difficulty. Before much can be done some sort of drainage is necessary. This is not the time for big drainage schemes, but much can be done by mole draining. If this is impracticable water may sometimes be led away by a water furrow into a ditch or sumpf. Sometimes, however, wet land does not want draining at all but only chalk or lime. This is particularly the case with the red stony clays of Herts, Bucks, Surrey and Kent, which are considerably improved by dressings of chalk or lime.

Liming or Chalking.

Liming is indispensable for wet land or sour land.

The crop tells pretty plainly whether it is needed: these are the signs:

1. If clover fails to start well, or to stand the winter, or looks bad in spring.

A Suffolk farm was recently examined by the writer where lucerne was failing in patches and weeds were consequently getting a firm hold. A similar occurrence was investigated on a Norfolk farm. The amounts of lime in the soil were:

	Suffolk	Norfolk	
On the good parts:	0·8	0·6	per cent. calcium carbonate.
On the bad patches:	0·07	0·2	,, ,, ,,

2. If swedes, turnips, or cabbages get finger and toe rather badly.

The Armstrong College experiments have shown that 2 tons per acre of ground lime, or $3\frac{1}{2}$ tons per acre of ground limestone, afford suitable dressings in this case[1].

3. If mayweed springs up vigorously among the wheat, or if spurrey, sorrel, or bent grass become prevalent.

Land that has laid wet through the winter ought to have lime in the spring: otherwise uneven patches may arise in the field, causing the crop to ripen unevenly, and giving weeds a good chance to develop.

At the present moment lime is of further value because it liberates the reserves of potash in the soil; indeed it is quite a sound policy to spend on lime the money that would normally be spent on potash.

Lime can be put on either as ground lime, limestone, or chalk.

Convenient dressings are:

From 10 cwts to 2 tons lime.

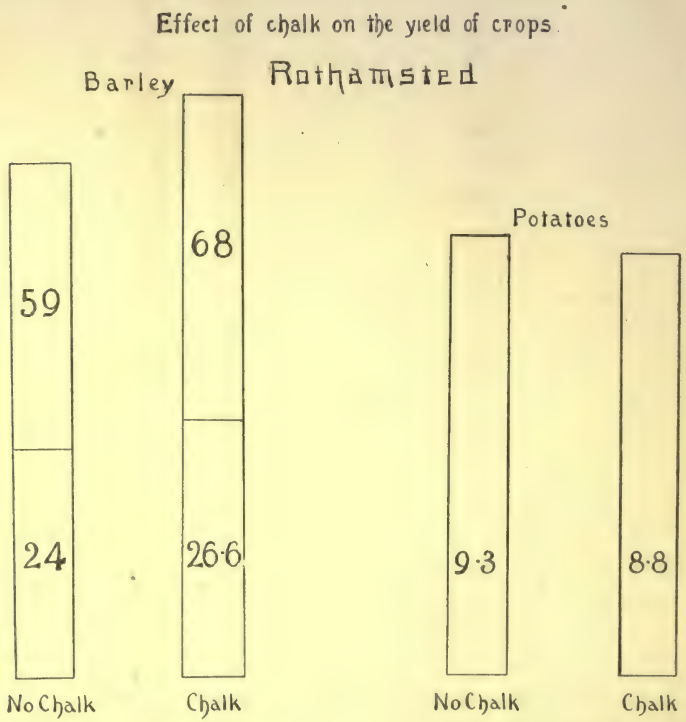
1–4 tons ground limestone.

20 loads small chalk, or 40 loads of larger lumps, such as are dug out of the ground.

The smaller dressings can be used for light soils, and the larger ones for heavy soils, or soils in bad physical condition.

[1] *Armstrong College Bull.* No. 12, 1915.

There are various qualities of lime which receive different local names. The best builders' lime is not necessarily the best for agricultural purposes. Cob lime may be used, and is cheaper than ground lime, but more costly to spread. Neither cob nor ground lime can be stored in bags. Sometimes lime ashes, lime mud, or other waste products are obtainable, but they are so variable in composition that they should only be bought on analysis.



The lower column stands for cwts of straw and the upper for bushels of grain.

Tons per acre.

Fig. 1.

The choice between ground lime and ground limestone is largely a matter of price: 12 cwts of ground lime have the same value to the farmer as 1 ton of ground limestone. Where the prices on this basis are equal there are some advantages in

favour of ground limestone. It has usually given somewhat better crop returns. It can also be stored in the bags in which it is sent, while ground lime cannot.

The smaller dressings of any of these can be put on with a distributer but the larger ones must be applied from a barrow, working against the wind.

Lime and limestone can go on either in winter or spring, and the most convenient crops on arable land are the seeds, the clover or the stubbles that are going to be ploughed up for corn or roots. All these may be expected to give immediate returns. It is shown in Aberdeen reports[1] that the lime must not be applied too close to the time of sowing the turnips, otherwise the yield may be depressed.

Nor should lime or limestone be put on to potatoes or oats unless actual trials have shown that benefit will be obtained; as a general rule these two crops respond less than others (Fig. 1): and in the Kilmarnock trials[2], lasting over eight years, potatoes were actually injured by lime, though oats benefited by it.

Basic slag reduces the need for lime, but superphosphate does not. Sulphate of ammonia increases the need for lime.

Green Manuring and Catch Cropping.

The ploughing-in of green crops is well known to bring about a great improvement in the soil. Very beneficial results have been obtained on light sands by means of lupines: elsewhere tares and mustard have proved beneficial.

On the old method a whole season was allowed for the green crops during which two, or sometimes three, could be taken, each being ploughed in before the next was sown. This method is still used in some of the best known experiments on the subject. In practice, however, it has been modified. Instead of devoting the whole season to green crops they are commonly grown between two staple crops so that the rotation is not disturbed: for this reason they were often called "stolen" crops in the olden days and

[1] *Aberdeen Bull.* No. 4, 1904.

[2] *West of Scotland Agric. Coll. Bull.* No. 55, 1911 (pp. 193–222).

are now called "catch" crops. A sufficient interval is necessary to allow of growth: they come in well, for example, between barley and mangolds. Instead of ploughing them in they are often fed off by sheep or cut green for horses and cattle. The effect on the soil is good whichever course is adopted, and each farmer must decide which is most convenient. In dry districts the chief difficulty is the water supply: the stubbles are often too dry to allow of germination of the seed of the catch crop, and after its growth it leaves the ground too dry for the next crop. In wet districts the drying caused by catch cropping is an advantage: it is claimed, for example, that the succeeding potato crop can be got in earlier because the land is dryer.

The effect on the soil depends on the nature of the crop and its bulk. Leguminous crops increase the stores of nitrogen in the soil: instances are afforded by the autumn sown trifolium harrowed in on the stubbles, or spring sown clover put in with the wheat or, in parts of Scotland, with the lea oats. Non-leguminous crops do not add nitrogen, but some of them, especially mustard, are nevertheless extremely effective.

Whether the crop is to be fed or ploughed in it must not be left after flowering time or it becomes too woody. And, of course, the bulkier it is the better, although even a small crop may have a good effect on the soil. There can be little doubt that the intelligent extension of this system would be very helpful.

War on Weeds.

Weeds do a considerable amount of damage, and ought to be kept down vigorously. It is difficult to find any good in them, and easy to find a good deal of harm: they take water and food that the crop ought to have: they interfere with the proper benefits that a fallow ought to produce: they harbour diseases and pests: and they have other faults. Therefore they should be kept down by cultivation, and, if necessary, by hand weeding done with child labour, if it can be obtained.

CHAPTER II

THE MANURE HEAP

The basis of any scheme of manuring must in general be farmyard manure, and the success of the scheme will vary as this is well or badly managed. Some 37 million tons of farmyard manure, valued at £11,000,000, are said to be made in the United Kingdom each year, thus it exceeds both in weight and in value all other fertilisers put together. But unfortunately there is often more waste of farmyard manure than of anything else on the farm, and most valuers would reckon that half of its goodness never reached the crop at all. Probably in no single direction is so much improvement possible as here.

Farmyard manure represents a mixture of litter with the parts of its food that the animal neither keeps in its body nor burns away into gas. It is, therefore, of the same nature as the food itself, i.e. as the crop. Changes take place during the passage through the animal's body; something is taken away, but nothing is added, and all that the animal can be said to do by way of improving the material is to break it down very finely and to kill the seeds. But even this is not done very well: horses, for example, allow live seeds to pass through their intestines, as shown by the crops of oats that sometimes spring up when horse manure is applied to the land.

The value of manure depends on three things: the food, the animal, and the method of storage.

As a general rule the richness of the manure depends on the amount of albuminoids or proteins in the food, and not on the amount of oil, because the albuminoids contain nitrogen, the most important constituent of the manure. Nowadays the potash is

becoming increasingly important. Thus, the following is the order of merit for some well-known feeding stuffs:

	Albuminoids or protein per cent.	Nitrogen per cent.	Potash per cent.	Manurial value per ton (Hall & Voelcker) £ s. d.
Decorticated cotton cake	43·1	6·9	2·0	3 4 9
Linseed cake	29·7	4·75	1·4	2 4 4
Coco-nut cake ...	20·8	3·4	2·0	1 14 7
Palm-nut cake ...	17·1	2·5	0·5	1 2 11
Oats	12·5	2·0	0·5	0 17 11
Oat straw	3·1	0·5	1·0	0 8 11
Swedes	1·5	0·25	0·22	0 3 7

But composition is not the only factor: digestibility is equally important. It so happens that the substances which the animal cannot digest also prove very difficult for the soil bacteria to attack, and so when they reach the soil they do not easily undergo conversion into plant food. These undigested substances form the faeces which are therefore the least valuable part of the manure. The digestible part of the food, on the other hand, is easily attacked by soil bacteria, and forms the best part of the manure. Of course if the animal kept all that he digested there would be none of it in the manure heap, but fortunately he does not. The oils, carbohydrates, and the carbonaceous part of the albuminoids are partly stored as fat and partly breathed out, but these are not the valuable fertilising constituents. The really useful fertilisers, the nitrogen and potash, are not stored except to a slight extent, and are not breathed out: they are excreted in the urine. This, therefore, represents the most valuable part of the manure.

Fatting beasts retain *least* of the nitrogen, phosphates, and potash in the food they digest, and, as they get the richest food, their urine is the richest on the farm.

Growing stock retain more, and therefore their urine is poorer. Milking cattle retain most, and on equal rations would give the poorest urine; but as they usually receive considerable quantities of highly nitrogenous food their urine is often very rich.

For 100 parts of nitrogen, phosphoric acid and potash in the food the following have been found in the dung:

	Fatting stock			Milking cows		
	In faeces	In urine	Laid on in flesh	In faeces	In urine	In milk
Nitrogen	30	65	5	31	52	17
Potash	—	—	—	15	75	10
Phosphoric acid	—	—	—	75·5	1·5	23

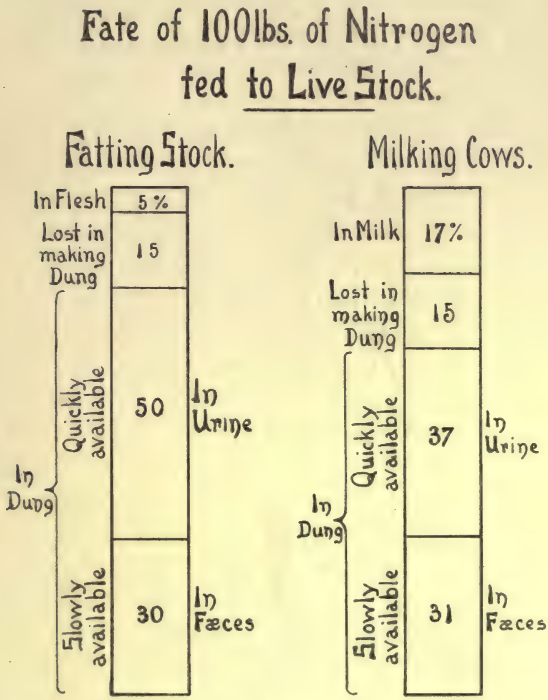


Fig. 2.

Seeing that most of the nitrogen and potash (see Fig. 2) are found in the urine, where also they are in the most satisfactory condition for the plant, it is obviously necessary to save the urine most carefully, otherwise much of the profit is lost. There are several ways in which this can be done. One is to use sufficient litter to absorb it all. Straw is the commonest litter, but if a man can get bracken he ought to do so, in order to set free some of his straw for military purposes. Bracken makes good manure for heavy soils, but does not answer so well on light

ones: it should be gathered in before the winter rains have washed out too much of its fertilising constituents.

Another way of saving the urine is to keep the beasts under cover directly they reach the stage of receiving cake. If you have not got a good covered yard arrange the threshing so that the beasts can be kept in part of the Dutch barn (Fig. 3). Manure made in this way keeps its urine well; its sole defect is that it may be rather dry. For autumn applications or for clamping this does not matter.

The manure thrown out from the horse-stalls is also dry, because of the large amounts of straw that horsemen tend to take when there is no check upon them. It is sometimes thrown into the open so that the rain may help to rot it down, but this procedure is very wasteful: it is better thrown into a covered yard under bullocks or pigs. If the yard is provided with a tank for liquid manure the drains leading to it should be put into order so that all the liquid may get there safely.

Time of application of the manure. The most economical procedure is to apply the manure at once to the land directly it is drawn out from the yards. The proper time for doing this depends on the crop and the climate. In districts where the rainfall is 35 inches or more the manure is best applied in spring for roots, potatoes, and, where the winter is mild, for clover leys. Berry[1] found in the west of Scotland that spring dressings on potatoes and turnips gave 50 to 60 per cent. increases, while autumn dressings only gave 25 per cent. increases over the control plots.

	Potatoes: Increase over unmanured plot						Turnips: Increase over unmanured plot					
	Weight per acre		Money value per acre			Per cent.	Weight per acre		Money value per acre			Per cent.
	tons	cwts	£	*s.*	*d.*		tons	cwts	£	*s.*	*d.*	
Spring application	4	2	9	3	2	157	6	2	2	8	6	141
Autumn ,,	2	1	4	12	0	126	3	14	1	9	6	125

Under drier conditions—30 inches or less of rainfall—winter dressings may be the better. Thus, at the Harper Adams Agricultural College[2], although the spring-manured potatoes made

[1] *West of Scotland Agric. Coll. Bull.* No. 65, 1914.

[2] *Harper Adams Report for* 1913.

Fig. 3. The loss in making farmyard manure is much reduced by keeping the animals under cover. If enough yard-space is not available part of the Dutch barn may be used. (Rothamsted.)

greater progress at first, they finally came out less than the autumn-manured crops. At Holmes Chapel[1] the following results were obtained in a four years test on loam and strong clay:

	Potatoes	Swedes	Mangolds
Dung applied in December...	5·7	14·5	22·1 tons per acre
Dung applied in April ...	5·5	12·8	17·7 ,, ,,
Advantage of winter dressing	—	1·7	4·4 ,, ,,

Apart altogether from the question of crop yield it is often more convenient to get the manure out in winter when other work is slack, and in the drier districts this can be done without serious loss. Some of the best Hertfordshire potato growers like to get part of their dung in the bouts in winter, so as to have things well forward in spring. As the rainfall only averages about 11 inches or less for the months November to March inclusive the

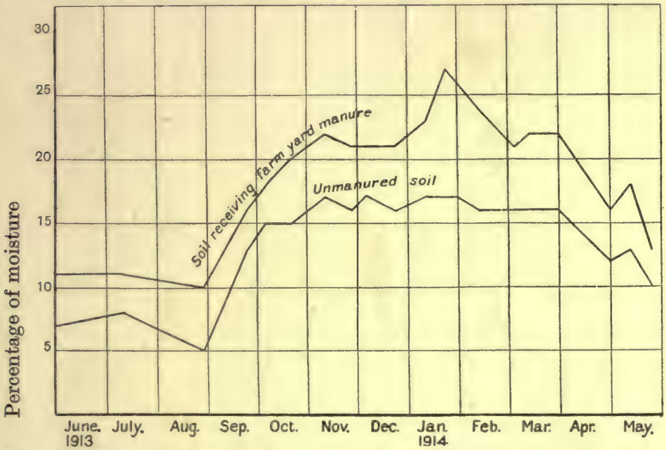


Fig. 4. Effect of farmyard manure on the moisture content of soils.

risk of loss is not serious, while the saving of time in spring may be considerable. Another consideration is that in these drier districts the dung, besides providing plant food, also improves the water holding capacity of the soil (Fig. 4). But, as Middleton has pointed out[2], this effect is only obtained when the dung is put on early enough to allow time for decomposition.

[1] *Holmes Chapel Report*, 1909.

[2] *Cambridge Reports*, Expts. on Potatoes at Newhouse Park Farm, St Albans, 1905, p. 16.

Storage of Dung.

It is not always possible to apply the manure straight away, and then it has to be stored. This is one of the most important operations on the farm, and one that shows up the quality of the farmer almost more than any other.

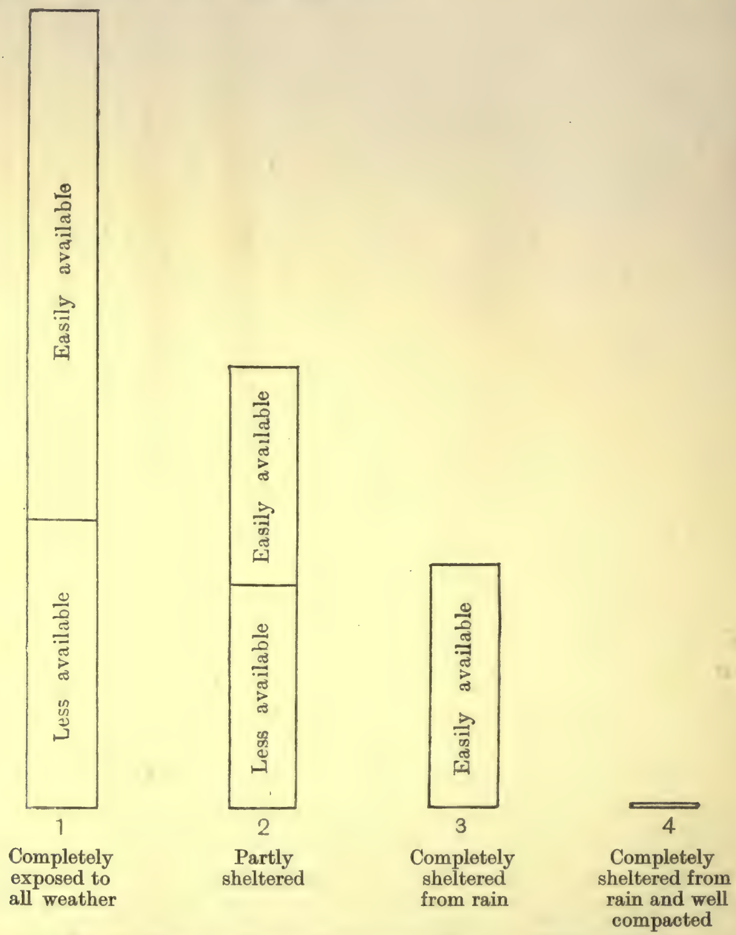


Fig. 5. Loss of nitrogen from manure heaps. (Rothamsted.)

There are two general rules:

1. The heap must be as much sheltered as possible from wind and rain.

2. It must be made as compact as it will go.

Fig. 5 shows the losses that may arise by neglecting these two rules. When the heap was thoroughly compacted and well sheltered there was no loss of nitrogen over a period of three months; when it was left exposed and not compacted the loss over the same period was 33 per cent. of the nitrogen, most of which was the best part, i.e. the most easily available for the crop.

It is a bad sign when the black liquid drains away from the heap, and a sure indication of bad making and bad placing. But the absence of the black liquid is no proof that all is well; there may still be serious losses unless adequate shelter is provided against the weather.

The worst way of dealing with manure is to throw it out daily from the byres into the open as is done in the dales in the North of England: the best way is to make a good solid clamp as firm as can be by drawing the cart over it, to make it as speedily as possible, and then to leave it undisturbed till it is wanted. The compact heap undergoes some change although it is not losing much nitrogen, in consequence of which it becomes more and more liable to lose nitrogen once air is admitted. Directly the heap is broken the manure should be got on to the land and worked in at once.

Fig. 6 shows how seriously the yield may be affected.

In horticultural practice it is not unusual to turn the heap so as to get well-rotted manure for top dressings. The process is very wasteful, and its only justification is that the ammonia which might scorch the foliage becomes lost. Spent manure from a hot bed would be far more economical. At the best storage is a necessary evil, justifiable only as a matter of convenience and to kill seeds. There seems little doubt that "long manure" is considerably more economical than "short manure" for the farmer. In the Yorkshire experiments[1] 10 tons per acre of fresh manure were applied to hay land in January, 1900, while an equal amount was clamped and left to rot till the following March, when it was applied. It then weighed 8 tons 1½ cwts.

[1] *Leeds Farm Guide* for 1906, p. 7 and for 1912, p. 10. In the springs of 1901, 2, 3, and 4 all the plots had received 1½ cwts per acre of nitrate of soda.

The yields of hay in cwts per acre were:

	Expt. 1 Beasts fed with decorticated meal		Expt. 2 Beasts fed with undec. cotton cake	
	Fresh manure cwts	Rotted manure cwts	Fresh manure cwts	Rotted manure cwts
Average of 3 plots for 1900	45·0	37·5	44·0	38·0
Average of 3 plots for each of next 4 years 1901–4	46·0	41·5	46·5	43·7
Total increase over 5 years from applying manure fresh instead of rotted	25·5	—	17	—

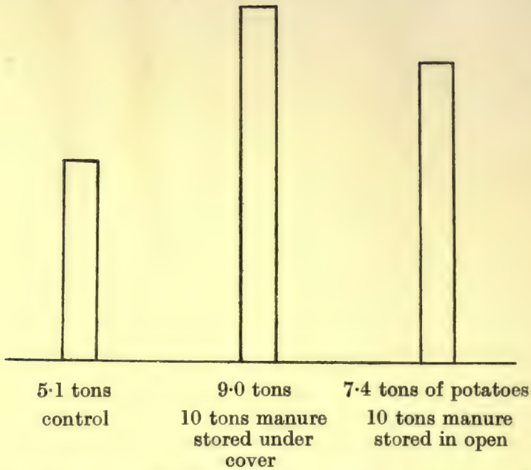


Fig. 6. Effect of storage of farmyard manure on yield of potatoes. (Rothamsted.)

On light land the long manure may "let in the drought" too much, but this can be obviated by ploughing it in sufficiently early to allow time for decomposition.

Fixers. It is sometimes suggested that various fixers might be added to the manure heap to help retain the ammonia, but there is no evidence that any of them is of value. The only one for which any advantage has been proved is a layer of earth on the top of the heap; but this is not always practicable.

Liquid manure. If you are unable to prevent liquid draining away from the farmyard manure then you certainly ought to use it, especially if the buildings include a tank into which it can

drain. The liquid should be pumped up into the water-cart and applied to the meadows or the leys; it is especially valuable just now because of its richness in potash. Hendrick[1] finds on an average that 1000 gallons ($4\frac{1}{2}$ tons) of the liquid contain about:

$20\frac{1}{2}$ lbs nitrogen, equal to that present in 100 lbs sulphate of ammonia,
3 lbs phosphoric acid, equal to that present in 25 lbs superphosphate,
46 lbs potash, equal to that present in 3 cwts kainit,

worth altogether more than £1, even at pre-war prices, and of course much more now. This was obtained from animals heavily fed with turnips (100 lbs per day per 1000 lbs live weight) and therefore passing large volumes of dilute urine.

In the Irish experiments[2] liquid manure applied at the rate of 16 tons per acre on hay land gave as good results as 16 tons of farmyard manure, or 5 cwts per acre artificial manures (1 cwt of nitrate of soda, 2 cwts superphosphate, and 2 cwts kainit). It is obvious that this is not material to be wasted.

Use of Farmyard Manure. Farmyard manure benefits both soil and crop. It improves the tilth of heavy soils, and increases the water supply of light ones. It nourishes the crop because it contains everything the plant requires. But it has first to decompose in the soil, and therefore the following rule holds good:

The full benefit of farmyard manure is obtained only when the soil is well cultivated, well drained, and well limed.

The composition of farmyard manure is as follows:

Composition of stable manure (lbs per ton)

	Good farmyard	Poor farmyard no cake	Town stables
Dry matter ...	613	610	694
Nitrogen ...	17	12	14
Phosphate (P_2O_5)	9	5	9
Potash (K_2O) ...	13	15	11
Water	1627	1630	1546

No one manure can possibly suit every crop, and farmyard manure is no exception. Turnips want more phosphates than it supplies: and mangolds can do with more nitrogen, while potatoes, generally, but not always, want more nitrogen, more phosphates, and more potash.

[1] *Aberdeen Bull.* No. 19, 1915.
[2] *Journ. Dept. Agric., Ireland*, 1913, **13**, 251.

Thus, for turnips the following results were obtained by Hendrick and Greig at Aberdeen[1] in 1904—a favourable season in which the manures were able to exert their full effect:

Dressing per acre	10 tons dung		10 tons dung + 1 dose of artificials		10 tons dung + 2 doses of artificials	
	tons	cwts	tons	cwts	tons	cwts
Yield of turnips	17	10¼	20	15½	22	12⅙

The dose of artificials consisted of $\frac{7}{16}$ cwt of sulphate of ammonia, 2⅞ cwts superphosphate, ⅜ cwt sulphate of potash.

These results were greater than could be obtained by increasing the dressing of dung:

Dressing per acre ...	No manure		10 tons dung		15 tons dung	
	tons	cwts	tons	cwts	tons	cwts
Yield of turnips ...	9	4¾	18	3½	19	14

In a poorer growing season, or where the conditions are such that the crop does not exceed 15 or 16 tons, these results are not obtained.

Thus at Rothamsted swedes in 1915 gave the following crops in tons per acre:

No manure	10 tons dung	10 tons dung + artificials	Artificials alone
9·6	12·9	12·9	12·7

Similar results were also obtained at Leeds[2].

The benefit of artificials is not confined to the root crop, they help the other crops in the rotation also. This is well seen in the Saxmundham experiments, the results of which are plotted in Fig. 7.

In using farmyard manure for swedes remember that finger and toe is carried by the manure, and if diseased roots have been fed to animals the crop receiving their manure is likely to get the disease also.

Mangolds want more nitrogen than farmyard manure supplies. The average of 27 years experiment at Rothamsted has been:

Dung alone	Dung + nitrate of soda
Tons per acre	Tons per acre
17·4	24·7

[1] *Aberdeen Bull.* No. 4, 1904. [2] *Leeds Report,* No. 3, 1898.

In a rotation experiment at Cambridge[1] the addition of artificials as well as farmyard manure not only increased the mangold crop, but also the two following crops:

	Mangolds, 1903		Oats, 1904		Seeds, 1905
			grain	straw	
	tons	cwts	bushels	cwts	cwts
10 tons farmyard manure to mangolds	24	8¾	65½	33¼	30½
10 tons farmyard manure + complete artificials to mangolds	31	13¾	70½	36½	46¾
Artificials only to mangolds	26	11½	64½	35	39

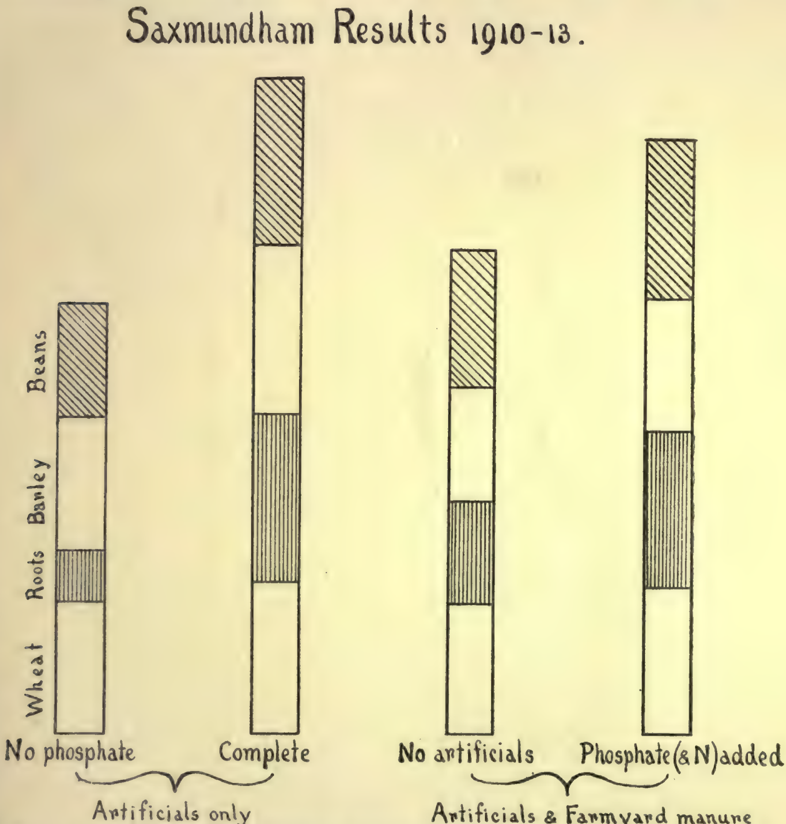


Fig. 7. Showing the advantage of using artificials with dung; and also that a shortage of dung may be met by complete artificials.

[1] *Cambridge Reports*, Guide to Experiments, 1905, p. 36.

The artificials supplied to the mangolds were $\frac{7}{8}$ cwt sulphate of ammonia, $1\frac{1}{4}$ cwts nitrate of soda, 6 cwts superphosphate, $1\frac{1}{2}$ cwts sulphate of potash. Nothing was added to the other crops.

Again, in a rotation experiment made by the Leeds University Agricultural Department 20 tons of dung supplemented by artificials gave larger returns than 38 tons of dung without artificials.

Potatoes often respond to a complete dressing of artificials in addition to dung. Thus, the following results were obtained in the Irish experiments carried out over the 11 years 1901–11 at 353 centres[1]:

	tons	cwts
No manure	4	0
15 tons farmyard manure per acre	8	4
20 tons farmyard manure per acre	9	2
15 tons farmyard manure per acre + 1 cwt sulphate of ammonia ...	9	3
15 tons farmyard manure per acre + 1 cwt sulphate of ammonia + 4 cwts superphosphate	9	19
15 tons farmyard manure per acre + 1 cwt sulphate of ammonia + 4 cwts superphosphate + 1 cwt muriate of potash	10	17

1 cwt of sulphate of ammonia is thus seen to be as effective as 5 tons of dung, while the addition of 4 cwts of superphosphate still further increased the yield, and 1 cwt of muriate of potash gave yet another 18 cwts of potatoes.

In other cases the increase in crops may be less, but there is an improvement in quality, always an important matter for potatoes: thus in the Yorkshire experiments[2] 10 tons of dung gave an increase of $2\frac{1}{2}$ tons in crop, but a second 10 tons only gave a further 16 cwts:

Large v. *small dressings of dung.*

	Garforth 1899–1903		Increase for each 10 tons dung		All centres		Increase for each 10 tons dung	
	tons	cwts	tons	cwts	tons	cwts	tons	cwts
No manure	7	$13\frac{1}{4}$	—		6	$4\frac{3}{4}$	—	
10 tons dung	10	4	2	$10\frac{3}{4}$	9	7	3	$2\frac{1}{4}$
20 tons dung	11	$0\frac{1}{2}$	0	$16\frac{1}{2}$	10	$3\frac{1}{2}$	0	$16\frac{1}{2}$

[1] *Journ. Dept. Agric., Ireland,* 1913, **13**, 264–276.

[2] *Leeds Bull.* No. 58. Report on the manuring of potatoes, 1899–1903 and 1904–5.

The addition of 6½ cwts of artificials (1½ cwts sulphate of ammonia, 3 cwts superphosphate, and 2 cwts sulphate of potash) gave only a small return in actual crop, but it improved the quality, lessened the proportion of diseased tubers, and left a bigger residue for the next crop:

	Garforth		All centres	
	tons	cwts	tons	cwts
10 tons dung	10	4	9	7
10 tons dung + 6½ cwts artificials	10	10¼	9	15¼

	Un-manured	10 tons dung	20 tons dung	10 tons dung + artificials	Complete artificials alone
Marks for quality	50	40	29	48	40
Percentage of diseased tubers	4·1	8·2	5·6	2·7	2·5
Next crop (Wheat)					
Grain, bushels	26¼	31¼	36½	35	31½
Straw, cwts	20	25½	32½	31½	23¼

Artificials alone proved satisfactory, giving not only good crops but also good quality:

	Garforth		Other centres	
	tons	cwts	tons	cwts
10 cwts artificials	11	11	9	14½
Unmanured	8	10½	6	3¾

Dung v. *Artificials.* In the 'sixties and 'seventies of the last century there was controversy as to whether dung or artificials were best. That is now settled in the way such controversies usually end: each side was shown to have a good deal of the truth, but not all the truth. The experiments already quoted show that a large dressing of dung—20 tons or so—is not much more effective than a smaller one—10 tons—while the best results are obtained by combining dung and artificials. This holds over the whole rotation.

Further examples will be given in a later chapter: meanwhile we need only emphasise that the large dressings of dung which some of the potato growers in the Home Counties found necessary when first they took the land over in poor condition, could well be reduced now that its price has gone up and transport difficulties have increased.

Residual effects. The farmer naturally expects the benefit of a dressing of dung to last throughout the rotation. The effects on the soil last for some years, but the supply of plant food may not.

Thus 10 loads of dung applied to potatoes would not leave much residue for the following wheat crop, because a ton of potatoes with the haulm (which is usually drawn off) contains about as much nitrogen as a load of dung; hence the 8 or 9 tons of potatoes that one hopes to get under modern management would nearly exhaust the stock. A spring dressing of artificials to the following crop affords the proper way of overcoming the difficulty.

In the experiments hitherto made the value of cake-feeding shows itself mainly in the first year; this does not confirm the popular view that the cake effects last for several seasons.

The following crop yields were obtained at Rothamsted:

Manure made by animals receiving	Year of application	2nd crop	3rd crop	4th crop
Cake	173	138	120	113
No cake	144	135	126	117
Unmanured	100	100	100	100

Similarly when cake is fed on the land the benefit is mainly confined to the succeeding crop; in the Back House Field Experiments at Cockle Park[1] the following results were obtained:

Plot	3rd Rotation	Swedes tons	Swedes cwts	Barley Grain bus.	Barley Straw cwts	Hay cwts	Oats Grain bus.	Oats Straw cwts	Value of all 4 crops £	s.	d.	Less cost of manure £	s.	d.
4	Artificials for swedes	19	6¾	23	11¾	38	40	16¼	24	3	8	9	2	9
5	+ ½ fed off by sheep receiving hay ...	18	7¾	34½	18¾	35½	43¼	20	26	7	2	9	17	7
6	+ ½ fed off by sheep receiving 10½ cwts cake	19	9¾	46	25¾	38¼	47¼	20½	30	0	7	12	11	9
	4th Rotation													
4	Artificials for swedes	16	8½	21½	14¼	14¼	54¼	37	22	19	8	6	4	6
5	+ ½ fed off by sheep receiving hay ...	15	2¾	23¼	16½	13¼	49¾	35½	22	0	9	3	15	3
6	+ ½ fed off by sheep receiving 10½ cwts cake	17	5¾	39	28¼	22¾	61	38¼	29	3	3	9	14	10

Quickly available nitrogen will not remain in the soil over a wet winter unless there is some crop to take it up. Put your best dung, therefore, on the crop that you hope will give the biggest return, and follow up with another crop as speedily as possible. Apply also the appropriate artificials so as to ensure getting the full value out of it.

[1] *Cockle Park Guide for* 1913.

CHAPTER III

ARTIFICIAL MANURES

It has been shown in the last chapter that farmyard manure is not enough for securing the best results, even where it can be got in sufficient quantity. Some of the various artificial manures must be used as well, and in order to get the most out of them it is essential to have clear ideas as to the nature and properties of the numerous substances passing under this name.

Very many artificial manures are already on the market, and new ones are perpetually being introduced. Fortunately they all fall into five well-defined classes, and it is tolerably easy to sort them out once their general properties are known. These classes are:

1. Nitrogenous.
2. Phosphatic.
3. Potassic.
4. Organic.
5. Mixed.

1. Nitrogenous Manures.

As their name implies these owe their value to their nitrogen, the most costly, and in this sense, the most important, of all plant foods. Nitrogen has to be in some combination before it can be taken up by the plant, and experience has shown that the best for the purpose is a nitrate. Nitrates are, therefore, the quickest in action of all this class of manures. It so happens, however, that the soil contains vast numbers of micro-organisms which rapidly manufacture nitrates out of other combinations of nitrogen, especially out of ammonium combinations and, rather

more slowly, out of animal or vegetable matter. It is not necessary, therefore, to add the nitrogenous food in the form of nitrates; other suitable combinations can be used, *provided the soil organisms can work.* Fortunately soil organisms want exactly the same soil conditions as plants, and if the soil is well cultivated, and sufficiently supplied with lime and organic matter, so that it is in a state favourable to plant growth, one can rest assured that it is also favourable to soil organisms and the manufacturing process.

But when conditions are not favourable to life, e.g. during very cold weather in spring, it is not wise to rely on the soil organisms, and in this case the nitrate should be supplied all ready for the plant.

The nitrogenous manures are:

Nitrate of soda. This is ready for use by the plant without undergoing any preliminary manufacturing process; it is, therefore, especially valuable in cold and wet conditions to ensure an early start in growth, and thus it forms a good spring dressing both for arable and grass land. When a young crop is suffering through the attack of an insect pest, a dressing of about 1 cwt per acre will help the plant to keep going, and to grow out of reach of the pest. Again, in spring time, after a wet winter, when wheat or winter oats are standing still and showing no signs of moving, a dressing is often useful in making them start.

It can be used for any crop: there is an idea that it is bad for barley, but no direct evidence seems to be forthcoming: certainly the Rothamsted barleys grown with nitrate of soda (and, of course, the other necessary plant foods) give a good sample, and this was also the case in the few Yorkshire trials that have been made[1].

Nitrate of soda is also useful for bulky leafy crops, such as hay, cabbages, rape, kale, mangolds, etc.

The disadvantage of nitrate of soda is that it injures the tilth of heavy soils. This can be corrected by mixing it with equal quantities of sulphate of ammonia. The mixture should be applied immediately it is made.

Nitrate of soda should be applied only as a top dressing after the plant is up. One to two cwts per acre is a suitable dressing; larger quantities may give additional yields, but in peace time

[1] *Leeds Bull.* No. 75, 1909.

the increases may not be worth the cost. Specially valuable crops well suited to nitrate, e.g. early cabbages and broccoli, may receive these larger dressings, and in Cornwall as much as 10 cwts per acre is sometimes used. In such cases the nitrate should go on in two or three lots, and not all at once.

Nitrate of soda easily washes away and will not remain in the soil over a wet winter; any that is not used by the crop in one season must be given up as lost. But when used as a spring dressing the risk of loss is only very small, unless one has the misfortune to put it on just in front of a long continued spell of heavy rain.

Nitrate of lime, where obtainable, has proved very valuable as a fertiliser. It resembles nitrate of soda in fertilising action, but seems to have no bad effect on the tilth.

Sulphate of ammonia. Next to the nitrates this is the quickest acting nitrogenous manure: it has to be changed into nitrates in the soil, but this does not take long under favourable circumstances, and in an ordinary way, unless it is desired to act on the plant at once, there is little to choose between sulphate of ammonia and nitrate of soda. Very careful comparisons have shown that the sulphate is not quite as good as the nitrate, its average return being about 80, when that of nitrate is 100; on the other hand it is often cheaper than nitrate. Sulphate of ammonia has no bad effect on the tilth, but rather the contrary, indeed as already stated it serves to correct any harm done by nitrate of soda.

It is the chief constituent of soot[1], and can be used in exactly the same way as soot: 1 to 2 cwts per acre form a suitable dressing. It can be used either as a top dressing or drilled in with superphosphate. Like nitrate of soda it cannot be expected to remain in the soil over a whole season, and any not taken up by the growing crop must be counted as lost. It is rather safer than nitrate of soda for use in winter or very early spring as it will survive considerable rainfall so long as the soil is not warm enough to induce rapid nitrification. As in the case of nitrate of soda the larger the dressing the greater the increase in crop: this is shown in the Rothamsted experiments with wheat (p. 44

[1] In some samples muriate of ammonia is said to be the chief constituent, but the same remark applies.

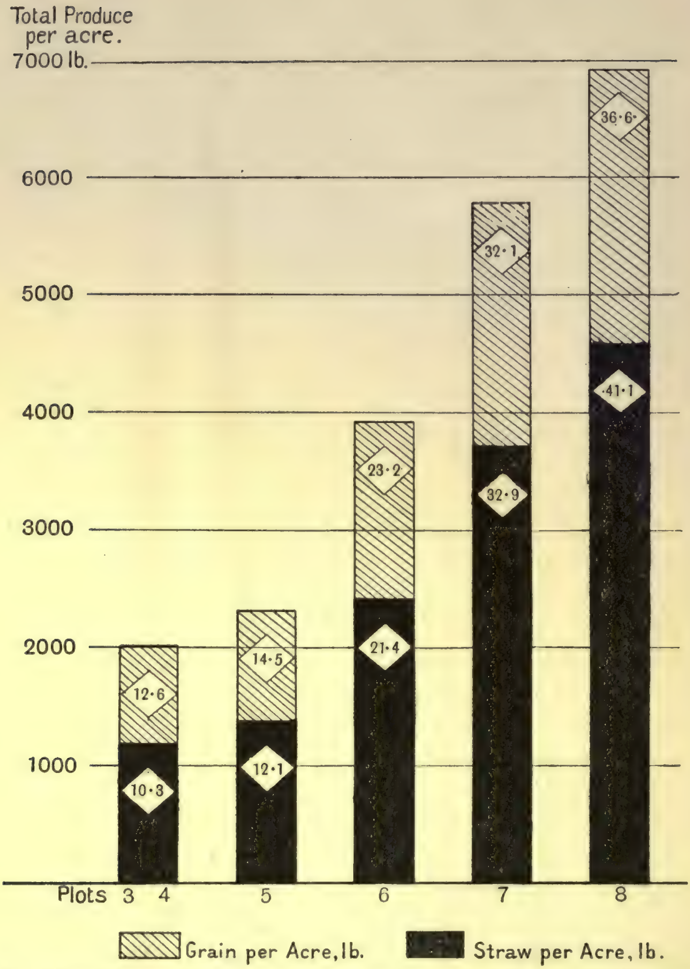


Fig. 8. Effect of extra nitrogenous manure on yield of wheat. Rothamsted.

Plots 3 & 4. Unmanured.
Plot 5. Potash and phosphates but no nitrogenous manure.
,, 6. Potash and phosphates and sulphate of ammonia containing 43 lbs N per acre.
,, 7. Potash and phosphates and sulphate of ammonia containing 86 lbs N per acre.
,, 8. Potash and phosphates and sulphate of ammonia containing 129 lbs N per acre.

The columns represent total produce per acre, but the figures in the diamond spaces give bushels of grain and cwts of straw per acre.

and Fig. 8) and with hay (p. 52): it is also demonstrated in the Irish experiments with potatoes:

Manures applied	Yield of potatoes, 5 years, 1908–12 tons	cwts
15 tons farmyard manure, 4 cwts superphosphate, 1 cwt muriate of potash + 1 cwt sulphate of ammonia ...	11	2
15 tons farmyard manure, 4 cwts superphosphate, 1 cwt muriate of potash + 2 cwts sulphate of ammonia ...	11	6
15 tons farmyard manure, 4 cwts superphosphate, 1 cwt muriate of potash + 3 cwts sulphate of ammonia ...	11	11

In peace times the extra yields are often not worth having, being produced at too great a cost, but in these days of high prices the extra yield may prove more profitable, and in any case it ought to be obtained if possible.

Muriate of ammonia is just as good as sulphate of ammonia.

Nitrolim. In general properties this is much like sulphate of ammonia, and has given very useful results. It has recently been made in granulated form, which is easier to handle than the older samples.

Slower acting nitrogenous manures. Shoddy. This waste product from the Yorkshire cloth mills has considerable fertilising value, and can be used without hesitation wherever it can be got cheaply. The best way of determining its value per ton is to get an analysis (nitrogen only) through the County Authority, and then to multiply each percentage of nitrogen by 6*s.*; the result gives a reasonable price at the Yorkshire mill. Thus, if the sample contained 7·5 per cent. of nitrogen a reasonable price would be 7·5 × 6*s.* = 45*s.* per ton, and it might be worth while to pay more. Carriage, of course, is extra.

Shoddy can be used on any crop, and gives a good return at once; thus, at Rothamsted the following results were obtained by the use of 10 cwts per acre:

	Mangolds 1911 tons	Wheat 1912 bushels of grain	Swedes 1913 tons	Barley 1914 total produce, lbs	Average of all crops and experiments, 1904–1915
10 cwts shoddy	14·7	28·4	10·7	4,516	140
Unmanured	11·7	24·0	7·9	2,805	100
Increase per cent.	26	17	35	61	40

On an average 10 cwts of shoddy per acre has given a 40 per cent. increase in crop, this being as much as was given by 16 tons of ordinary farmyard manure per acre.

Shoddy can go on in winter, or at any time up till March. It must, however, be applied before the last ploughing as it has to be worked into the land. We have never used it as a top dressing at Rothamsted.

Rape cake, or other oil seed residues. These are so well known that it is not necessary to say much about them. They rapidly yield nitrates in the soil, and are in such high favour that farmers are sometimes asked to pay rather a fancy price for them: it is doubtful whether any of them is really worth more than half the price of good fish guano.

Sewage sludge. When sewage sludge can be bought cheaply it may be of some use, especially in wet districts, but no general opinion can be given, and it ought not to be used without first consulting the County Adviser. Our experiments at Rothamsted have not given satisfactory results, and it would not have been worth our while to pay more than a few shillings a ton even for the dried powdered material. In some cases, however, the sludge contains so much lime that it proves beneficial, but care should be taken not to pay too much for it.

2. Phosphatic Manures.

Phosphates may be given in any of four different forms: superphosphate, basic slag, bones, and rock phosphate.

Phosphates represent the great need on land that is highly farmed, and the more a man spends on dung or cake the more he ought to spend on phosphates to get the full worth of his money. Their great value lies in fostering root development, early growth and early ripening. Further, they counteract any tendency to rankness, and enable the plant to make full use of the farmyard manure and cake residues without becoming too rank and coarse. In horticulture they induce the hard growth wanted in young plants.

Superphosphate. Of all phosphatic fertilisers this is the most soluble and the quickest in action. Its effect in promoting root

development is especially valuable for shallow rooted crops and for short lived crops which have to grow quickly: thus, it acts well for barley, swedes, and potatoes.

For the same reason it is very useful on heavy land after a wet winter in helping the young plants to form roots.

The effect of the early start persists throughout the life of the plant, and ripening is hastened. Wherever there is danger of late harvests superphosphate should be used for the corn.

All heavy soils and soils inclined to be sticky in spring respond to superphosphate, and two classes of soil respond in an extraordinary degree: the clay fen soils, which often want nothing else in the way of artificial manures, and the heavy soils in wet regions, e.g. the north country, on the Boulder Clay, Wales, etc. Light soils do not usually want phosphates so much except in cold or wet climates, or after a crop has been eaten on the land by sheep receiving also cake or corn.

The dressings may be liberal, from 3 to 5 cwts per acre; there is no fear of loss, and whatever is left by one crop remains for the next. It can safely be mixed with sulphate of ammonia so as to put on the two together. If necessary it can also be mixed with nitrate of soda, but this mixture should be applied at once as it does not keep well.

As a rule the yield does not go on increasing with the dressings as in the case of sulphate of ammonia or nitrate of soda, and it is not usually worth while giving more than 5 cwts per acre. In some of the special cases above mentioned, however, the crop goes on responding long after this dressing is exceeded. Thus the Cambridge experiments on fen soils gave the following results per acre[1]:

With mangolds	tons	cwts	With potatoes	tons	cwts
No manure	11	2½	No manure	5	12
3 cwts superphosphate ...	16	2	4 cwts superphosphate ...	7	15
6 ,, ,, ...	21	13	8 ,, ,, ...	8	10

[1] *Cambridge Farmers' Bull.* No. 6. Two of the soils overlay clay, the third was over gravel.

Increases, but on a smaller scale, have also been observed by Greig in some of the Aberdeen experiments on turnips[1]:

	Per acre tons	Per acre cwts
Sulphate of ammonia ($\frac{6}{7}$ cwt), sulphate of potash (1 cwt) + $2\frac{1}{2}$ cwts superphosphate	15	18
Sulphate of ammonia ($\frac{6}{7}$ cwt), sulphate of potash (1 cwt) + 5 cwts superphosphate	17	8
Sulphate of ammonia ($\frac{6}{7}$ cwt), sulphate of potash (1 cwt) + 10 cwts superphosphate	18	7

Basic slag. This fertiliser is not quite so soluble as superphosphate, but on the other hand it contains more free lime. It is particularly associated with grass land, and is dealt with from that point of view in Chapter v. But it is also useful on arable land and has given good results for leguminous crops, and for swedes and turnips, especially where finger and toe is common. In the Irish experiments it gave approximately the same results as superphosphate, both for turnips and for hay[2]:

Average yield of turnips per acre, 5 *years*, 1908–12.

Amount of phosphate per acre	With dung (177 centres)				Without dung but with sulphate of ammonia and kainit (109 centres)			
	Basic slag		Superphosphate		Basic slag		Superphosphate	
	tons	cwts	tons	cwts	tons	cwts	tons	cwts
4 cwts	22	17	22	19	21	18	22	11
5 cwts	23	9	23	16	22	17	23	12
6 cwts	24	6	24	9	23	16	24	12

Yield of hay (1912 *and* 1913).

	1912 (23 centres)		1913 (26 centres)	
	tons	cwts	tons	cwts
Superphosphate 2 cwts, nitrate of soda 1 cwt and kainit 2 cwts	3	2	3	$1\frac{3}{4}$
Basic slag 2 cwts, nitrate of soda 1 cwt and kainit 2 cwts	3	$1\frac{3}{4}$	2	$19\frac{3}{4}$

In the Glasgow experiments[3] basic slag gave smaller crops of turnips than superphosphate, but the feeding value, as shown by

[1] *Aberdeen Bull.* No. 10.

[2] *Journ. Dept. Agric., Ireland,* 1914, **14**, pp. 295 (turnips) and 259 (hay).

[3] *West of Scotland Agric. Coll. Bulls.* Nos. 15 and 23.

the live weight increase in sheep, was higher, so that on the whole the slag came out the better. In the Aberdeen experiments there was little to choose between them, but the largest crops were obtained from a mixture of the two.

There has been a good deal of discussion as to whether high grade or low grade slags are most economical and what degree of solubility in citric acid is desirable. Experiments on these points are still in progress.

Bones. The various bone manures are very popular, but on the whole they have not proved as successful as superphosphate for turnips, or as slag for grass. Steamed bone flour is useful in dry situations, while bone meal has proved useful for potatoes in the place of superphosphate. There is no justification for paying any fancy price for bone manures, but they may come in very handy in case of shortage.

Mineral and patent phosphates. Some of these have proved distinctly useful, though not equal to superphosphate or slag. They should be offered at a low price, but as they are very variable in nature they should only be used on expert advice.

3. Potassic Manures.

Potassic manures are wanted:

1. For potatoes, mangolds and leguminous crops.
2. On other crops when extra vigour is wanted, e.g. when diseases occur.
3. On light sand or thin chalk soils.

But as they cannot be obtained now, the main question is how to do without them.

There are two ways: to use other sources of potash instead of the ordinary Stassfurt salts, and to make fuller use of the potash supplies already in the soil.

Sources of potash other than the Stassfurt salts.

Various ashes, etc. Every farmer obtains a certain amount of potash on his own farm in the course of the year, and it is very desirable that some of this should be saved. The ashes of hedge trimmings contain up to 10 per cent. of potash, nearly the same

amount as in kainit; by keeping the hedges very closely trimmed and burning the trimmings one therefore obtains the double benefit of small clean hedges and extra supplies of ash. Brushwood, useless fallen timber and other wastes from woods and coppices yield ash containing 5 to 8 per cent. of potash and 20 to 40 per cent. of lime; this sort of material can well be burnt because it only harbours pests. Burnt hayricks, the waste cavings, dust, etc. obtained during threshing, also yield an ash containing up to 10 per cent. of potash. All these should be carefully collected. The potash is in a highly available form, indeed it is so soluble that a single night's rain may wash half of it away: the ash, therefore, has to be collected as speedily as possible, or if it is too hot to be got in before the rain comes on, it must be sheltered in some way. The ash tends to absorb water from the air, so that it does not keep well, and it is difficult to spread because of its lightness. But both these difficulties can be overcome by mixing it with superphosphate.

Coal ashes are of no value.

Seaweed contains a good deal of potash, and should be used as much as possible; in 1 ton of the fresh weed there is as much potash as in 1½ cwts of kainit. It is greatly to be regretted that no satisfactory seaweed industry has yet been developed[1].

Farm products. All crops contain a good deal of potash, especially roots, leaves and straws. Grains and seeds on the other hand contain least. The amounts present are as follows:

Potash in various farm crops.

	Mangolds		Turnips	Potatoes	Meadow	Wheat	
	roots	leaves	roots	tubers	hay	straw	grain
	tons	tons	tons	tons	tons	cwts	bushels
Size of crop per acre	40	15	20	8	1½	36	40
Weight of potash (K_2O) removed, lbs per acre ...	400	150	110	108	54	32	12

The animal products of the farm are very poor in potash. For every hundredweight of flesh laid on, a fattening animal keeps only 2 ozs of the potash present in its food. Dairy stock take a bigger toll, but not very much, 1000 gallons of milk only containing

[1] See Hendrick, *Journ. Bd. Agric.*, 1916, **22**, 1095.

about 16 lbs of potash. Thus, in the ordinary way of farming the amount of potash sold off is very small, only the potato crop taking away any considerable amount. The bulk of potash is in the crops which are fed on the farm, and it is not retained by the animal, but passes out in the liquid excretions.

It is therefore imperative that the liquid should be saved. This is dealt with on p. 14.

Root residues. When grass land or clover leys are ploughed up decay sets in, and the potash in their roots, stems, leaves, etc. becomes liberated. No exact estimate is possible of the amount, but it is certainly considerable. A crop grown on ploughed up ley or grass land, therefore, needs less potash than usual.

The reserves of potash in the soil.

Although potassic fertilisers are easily soluble in water, they do not readily wash out from the soil, because they are absorbed or "fixed" by some of the soil constituents. Wherever high farming has been practised the amount of potash supplied in the imported fertilisers, stable manure, or feeding stuffs may well have been greater than the amount removed. There has therefore been some accumulation in the soil, which can now be treated as a reserve, and drawn upon for the needs of the crop. There are two ways of doing this:

1. Salt or sulphate of soda may be applied.
2. The land may be limed.

Salt. On any land known to benefit by kainit it is advisable to try dressings of salt. The most suitable crops are mangolds, cereals and grass land.

Mangolds gave the following results at Woburn[1]:

	Unmanured	No salt	1 cwt salt	2 cwts salt	4 cwts salt	6 cwts salt
Mean of 4 varieties, tons per acre	27·0	30·9	30·6	34·3	34·6	36·3

All plots except the unmanured received 1 cwt nitrate of soda per acre.

[1] *Journ. Roy. Agric. Soc.* 1908, **69**, 355.

At the Harper Adams College[1] the results for the three seasons 1913–15 were:

No salt	5 cwts salt after sowing,	10 cwts salt after sowing	
27¼	35¼	36	tons per acre

All plots received farmyard manure, and in addition 2 cwts of dissolved bones, ½ cwt superphosphate, and ½ cwt sulphate of ammonia per acre.

In the Cockle Park trials[2], 2 cwts of salt increased the yield of mangolds by nearly 4 tons per acre on an average of 5 years. Good results have also been obtained elsewhere.

Cereals, especially wheat, used to receive salt in the old days, and might well do so now on thin light or chalky soil. Only a few experiments have been made on the subject: in Yorkshire salt increased the yield of barley, both in the dry season of 1901 and the wet season of 1903, but the results of later experiments were not conclusive[3].

There is considerable evidence that sulphate of soda liberates potash from the soil. It has been used for many years at Rothamsted, often with good effect and never with bad. It must, however, be free from acid. Some samples contain a fair quantity of potash: one recently analysed at Rothamsted had as much as 23 per cent., equivalent to 47·4 per cent. sulphate of potash.

Lime. For leguminous crops it is probably safer to use lime than salt; this is dealt with on p. 3.

Potatoes. This crop is too valuable to allow of any risks, and it should receive all the potash that can be got together by purchase, ashes, seaweed, etc. No one, however, need reduce his area of potatoes because he is short of potash. Most large growers have used it liberally for a number of years, and could probably leave it out for a time without harm. But this risk could not always be taken. Much depends on the nature of the soil, and on some land it is still worth spending a good deal on sulphate of potash.

Farmyard manure as a saver of potash. Farmyard manure is fairly rich in potash, a 10 ton dressing supplying no less than

[1] The experiment is described in *Harper Adams Report for* 1909, p. 14.

[2] *Cockle Park Bull.* No. 16, 1911.

[3] See *Leeds Bulls.* Nos. 22 and 39 for the earlier experiments, and No. 75 for the later ones.

150 lbs, equivalent to nearly 3 cwts of sulphate of potash. It therefore reduces the need for potassic fertilisers. This is shown in one of the Back House field rotation experiments at Cockle Park[1]. The soil is a light sandy loam of good texture, overlying Millstone grit sandstone: it is poor in potash, and just the kind of soil one would expect to benefit by potassic fertilisers. And so it does when artificials alone are used: the value of the produce fell off by over 17*s.* per acre per annum when potash was left out. But when farmyard manure was used the omission of potash had not nearly so bad an effect:

	Swedes 1909		Barley 1910		Hay 1911	Oats 1912		Value of 4 crops over unmanured			Gain, less cost of manures		
			Grain	Straw		Grain	Straw						
Plot	tons	cwts	bus.	cwts	cwts	bus.	cwts	£	*s.*	*d.*	£	*s.*	*d.*
8 Artificials alone, 6 cwts for swedes, also for hay ...	16	13½	22½	17½	25¼	48¾	38½	9	9	0	6	2	2
10 Artificials alone, no potash	10	17	19	15¼	20	52½	37½	6	0	3	3	9	5
19 Dung + ½ dressing artificials for swedes, also for hay	24	4½	44	30¾	29¼	56	35¼	17	17	4	11	3	11
22 Ditto, but without potash	21	15¼	45¾	33½	30½	52	36¾	17	3	0	10	17	7

The dressings were:

Dung, 10 tons per acre.

Artificials (full dressing), 7 cwts per acre (1 cwt sulphate of ammonia, 5 cwts superphosphate, 1 cwt muriate of potash).

The after effects. It must be clearly remembered that all these are only emergency measures, strictly representing the liquidation of capital. As soon as cheap potash is available once more it must be applied to the land so as to replace the stocks now being drawn upon.

The value and price of manures.

Owing to difficulties of transport the farmer can no longer rely on getting just the manure he wants at the time he wants it, and he may have to take something else. He must therefore be

[1] *Cockle Park Bull.* No. 19, p. 47, 1913.

able to compare their cost, and this is done on the basis of unit values.

The unit value is the cost of 1 per cent. per ton; it is got by dividing the cost of the manure by the percentage of nitrogen, phosphate, or potash. Thus, the unit value of nitrogen in sulphate of ammonia containing 20 per cent. of nitrogen is at present:

$$\frac{\text{Cost of manure}}{\text{Percentage of nitrogen}} = \frac{£17}{20} = 17s.,$$

while that of nitrate of soda is rather higher.

The unit value of soluble phosphate in 30 per cent. superphosphate is

$$\frac{£4}{30} = 2s.\ 8d.$$

The phosphates in guano, fish, meat meal, and basic slag are considered of less value than in superphosphate, and those in bone meal, bone flour, and rape meal still less. The nitrogen is, in peace times, reckoned to be worth more than that in nitrate of soda or sulphate of ammonia, but in war time it ought not to increase much in price, as it is not wanted for munitions; it can safely be put at 18*s.* per unit.

Bone flour containing 2 per cent. of nitrogen and 60 per cent. of phosphates was offered at £6. 10*s.* delivered.

2 units nitrogen at 18*s.* are worth £1. 16*s.*, leaving £4. 14*s.* to pay for 60 units of phosphate,

$$= \frac{£4.\ 14s.}{60} = 1s.\ 6d. \text{ per unit,}$$

a very reasonable sum, only a trifle over peace prices. The offer therefore was a good one.

Rape dust containing 5 per cent. nitrogen and 4 per cent. phosphate was offered at £8. 10*s.* per ton f.o.r.

$$4 \text{ units phosphate at } 1s.\ 6d. = 6s.,$$

leaving £8. 4*s.* to pay for 5 units of nitrogen,

$$= \frac{£8.\ 4s.}{5} = 32s.\ 10d. \text{ per unit of nitrogen,}$$

a very high price which could hardly be justified except in extreme cases.

The following are prices which obtained just before the out break of the war:

	Percentage composition N	phosphate	K_2O	Price per ton, cash £ s. d.	Unit value of N £ s. d.	phosphate s. d.	K_2O s. d
Nitrate of soda	15	—	—	11 10 0	0 15 4	—	—
Sulphate of ammonia ...	20	—	—	12 10 0	0 12 6	—	—
Peruvian guano	6	30	2	10 5 0	1 4 0	1 9	4 6
Fish ,,	9	8	—	9 2 6	0 19 0	1 9	—
Meat ,,	6·5	17	—	7 10 0	0 18 0	1 9	—
Rape cake ...	4·75	4	—	6 0 0	1 3 0	1 6	—
Dried blood ...	12	—	—	12 0 0	1 0 0	—	—
Horn	12	—	—	12 0 0	1 0 0	—	—
Shoddy ...	12	—	—	6 0 0	0 10 0	—	—
,, ...	5	—	—	2 0 0	0 8 0	—	—
Two low grade manures (*a*)	1·8	22	2	5 5 0	1 16 1	1 5	4 6
(*b*)	2	4	—	4 10 0	2 2 2	1 5	—
Superphosphate	—	30	—	2 15 0	—	1 10	—
Basic slag ...	—	24–42 (20–34 soluble)	—	1 7 0 to 2 12 0	—	1 5	—
Sulphate of potash ...	—	—	48·5	11 7 6	—	—	4 8
Kainit ...	—	—	12·0	2 17 6	—	—	4 9

Current unit prices are published each month in the *Journal of the Board of Agriculture.*

Comparisons between nitrate of soda and sulphate of ammonia, and between the various phosphatic manures, may be facilitated by the following tables:

	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.
When nitrate of soda is	11 10	12 0	13 0	14 0	15 0	16 0
Sulphate of ammonia should be about ...	12 10	13 1	14 3	15 4	16 6	17 8

	£ s.	£ s.	£ s.	£ s.	£ s.	£ s.
When sulphate of ammonia is	12 10	14 0	15 0	16 0	17 0	18 0
Nitrate of soda should be about	11 10	12 18	13 16	14 14	15 13	16 11

	£ s. d.	£ s. d.	£ s. d.
When 30 % superphosphate is	2 15 0	3 0 0	3 10 0
Then a high grade basic slag (34 % soluble) should be about	2 12 0	2 17 0	3 6 0
Steamed bone flour and bone meal should be about ...	0 1 5	0 1 6	0 1 8 per unit of phosphate

	£ s. d.	£ s. d.	£ s. d.	
When 30 % superphosphate is	4 0 0	4 10 0	5 0 0	
Then a high grade basic slag (34 % soluble) should be about	3 15 0	4 5 0	4 14 0	
Steamed bone flour and bone meal should be about ...	0 1 10	0 2 0	0 2 2	per unit of phosphate
Allowing	0 18 0 per unit of nitrogen			

5. *Mixed manures and proprietary articles.* It is often an advantage to buy the manure ready mixed, but two rules should be observed:

1. Mixed manures must only be bought from firms of repute, as they allow considerable scope for dishonest practices.

2. Before purchasing the prices should be compared as shown above with those of the ordinary artificial manures. At present prices one would allow about 20*s.* for each per cent. of nitrogen, 3*s.* for each per cent. of soluble phosphate, 2*s.* for each per cent. of insoluble phosphate, and 10*s.* for each per cent. of potash[1] in the fertiliser. Thus, if a manure is guaranteed to contain 4 per cent. nitrogen, 20 per cent. phosphate,—half soluble and half insoluble,—and 2 per cent. potash, a fair price at the time of writing would be:

		£ s. d.
Nitrogen	$4 \times 20s.$	4 0 0
Phosphates	10 at 3*s.* + 10 at 2*s.* ...	2 10 0
Potash	2 at 10*s.*	1 0 0
		£7 10 0

Anything in excess of this price would be paid for the convenience of having the mixture made up. These figures represent top grade materials, but there is nothing to compel the maker to use such good stuff, and nothing to show that he has done so, except the crop results: it would be quite easy to use a mixture of shoddy at about 8*s.* and sulphate of ammonia at about 17*s.* per unit of nitrogen, making an average of 12*s.* per unit. It is to avoid trouble of this sort that farmers have often been recommended to make their own mixtures instead of buying them.

[1] War price only; in peace time it was 4*s.* 6*d.* Potash fertilisers cannot be bought at this price and where they are known to be indispensable the farmer must be prepared to pay more. But in ordinary practice and with the ordinary run of mixed manure I think this is a fair allowance.

Storage and mixing of artificials. All artificial manures must be ordered well beforehand, stored in a dry place, and mixed on a dry floor.

Basic slag and sulphate of ammonia should not be mixed, but applied separately.

Dissolved bones and nitrate of soda should not be mixed, but applied separately.

Superphosphate and nitrate of soda can be mixed, but must be applied at once.

Superphosphate and sulphate of ammonia can be mixed, and will keep indefinitely.

CHAPTER IV

THE MANURING OF ARABLE LAND

Potato and Root Crops.

We start with these crops because they usually form the basis of the rotation.

Potatoes. For some time potatoes have been the most profitable of the root crops. The extension of potato culture was one of the most important factors in the revival of agriculture 20 years ago, and some of the methods that were successful then still remain without much change. In parts of Hertfordshire, for example, the Scotch farmers that came south with potatoes and dairy cows found land rather run out, cheap stable manure obtainable from London, and low prices for wheat. They made the best of these conditions by applying heavy dressings of dung to the potatoes—about 20 tons to the acre—and nothing to the wheat. This practice is still common. But circumstances have changed since then: the land is no longer run out, London stable manure is no longer cheap, and wheat is high in price. Therefore the method may well change.

It is shown in Chapter II that a small dressing of dung—10 tons to the acre—supplemented by artificials usually gives larger crops of better quality than larger dressings of dung.

A suitable dressing is 10 to 15 tons of dung at the time of planting in the north, but in winter, if possible, in the south and west (see p. 10), and supplemented by the following:

1 cwt sulphate of ammonia, 4 cwts superphosphate, 1 cwt sulphate of potash; or, 1½ cwts sulphate of ammonia, 4 cwts superphosphate, 1½ cwts sulphate of potash.

In the Glasgow experiments[1] a mixture of basic slag and superphosphate (3 cwts of each) was better than superphosphate alone; at Holmes Chapel[2] steamed bone flour (3 cwts) was better than either, and in the Northumberland and Durham districts 2 cwts high grade basic slag is recommended in place of the superphosphate.

Where dung was applied the omission of potash[3] did not prove serious in cool, moist districts, e.g. in Lancashire[3], Wales[4], and Somerset[5], or in land in good condition in Herts[6]. In these circumstances, therefore, the grower need not be over anxious if he cannot get potash, so long as he has dung; he can use 1 to 2 cwts of sulphate of ammonia, and 4 cwts of superphosphate or 2 cwts of bone meal in addition to the dung.

In the more forward districts on lighter soils, however, e.g. Herefordshire[7], Devon[8], Bedford[9], Wiltshire[10], potash proved more necessary, and greater efforts must be made to secure it.

On peaty soils the dressings of sulphate of ammonia can be reduced, and in the fens it can be dispensed with altogether.

On clay fen land the following has worked well[11]:

No dung, up to 8 cwts superphosphate,

and on clay silt lands:

No dung, 4 to 6 cwts superphosphate, ½ cwt sulphate of potash.

On the whole sulphate of ammonia and superphosphate have proved better than nitrate of soda and basic slag, both of which rather tend to set up alkaline conditions favourable to scab. Lime is to be avoided for the same reason.

No grower should omit to spray the main crop varieties.

[1] *West of Scotland Agric. Coll. Bull.* No. 51, 1909.

[2] *Holmes Chapel Year Book*, 1909.

[3] *Lancs. C.C. Farmers' Bull.* No. 13.

[4] *Aberystwyth Rept.* 1906.

[5] *Somerset C.C. Rept. on Field Trials*, 1900–1908

[6] *Herts C.C. Leaflets*, Nos. 6 and 7.

[7] *Hereford C.C. Bull.* No. 2.

[8] *Devon C.C. Report*, 1907–1909.

[9] *Beds C.C. Report on Demonstration Plots*, 1907.

[10] *Wilts C.C. Results of Field Demonstrations*, 1908–9.

[11] In the Northumberland experiments basic slag was better than superphosphate.

Mangolds. The mangold is a very seductive crop because it responds to liberal manuring; indeed, it gives more produce per acre than any other.

It is shown on p. 16 that mangolds need nitrogen in addition to dung. Suitable dressings are:

Up to 20 loads of dung,

1 cwt sulphate of ammonia, 2 to 4 cwts superphosphate or basic slag[1], 2 to 4 cwts salt in the drills;

$1\frac{1}{2}$ cwts nitrate of soda as a top dressing when the plants are hoed and singled.

On peaty soils or heavy clay soils in cool, wet districts, the sulphate of ammonia can be omitted and the phosphate increased. Slag is then better than superphosphate.

On black fen soils, however, 6 cwts superphosphate alone, without dung or other fertiliser, proves sufficient.

Swedes and turnips. It was the turnip crop that revolutionised British farming nearly 200 years ago, but if south country and East Anglian farmers kept closer accounts some of them would begin to ask whether it has not outstayed its welcome. It may be doubted whether crops of swedes and turnips under 20 tons per acre bring in sufficient revenue to pay the cost of production. The problem of finding a substitute is one for the future; meanwhile we have to make the best of the crop as we have it.

The main expense is the cultivation, and this is the same whether the crop is large or small.

The chief factor limiting the yield is the climate: no amount of manuring can get over this difficulty.

If the climate allows more than 20 *tons per acre* liberal manuring may be adopted. A good dressing of dung can be given, supplemented by artificials rich in phosphates.

Suitable dressings are:

10 to 15 tons farmyard manure, 4 to 6 cwts superphosphate or basic slag[2],

1 cwt sulphate of ammonia, in the drills.

On peaty soils the sulphate of ammonia may be omitted, but,

[1] In the Northumberland experiments basic slag was better than superphosphate.

[2] Basic slag is preferable to superphosphate wherever finger and toe is prevalent. In some of the experiments it also gave roots of better feeding value.

if it can be got, $\frac{1}{2}$ cwt muriate of potash or 4 cwts of kainit should be added; 4 cwts salt may be used instead. A sprinkling of nitrate of soda may be given at the time of singling.

In moist districts on the heavier soils the turnip crop can do better without farmyard manure than either mangolds or potatoes, and if there is any shortage the following may be used:

> 4 to 6 cwts superphosphate or basic slag, 1 cwt sulphate of ammonia, and 1 cwt sulphate of potash in the drills; 1 cwt nitrate of soda as a top dressing at the time of singling: no farmyard manure.

This dressing (using basic slag and not superphosphate) would also be applied where finger and toe is prevalent. It has been shown that this disease is transmitted through dung; the safest way of eradicating it is to lime the land, and use artificials only for cruciferous crops (turnips, cabbages, etc.), which take the disease, keeping the farmyard manures for cereals, grass, potatoes, mangolds, etc., which do not.

If the climate only allows 15 *to* 20 *tons per acre* it is inadvisable to spend too much on manure, as the crop is hardly likely to pay even for the cultivation.

Dung will usually be necessary to hold moisture in the soil for the plant: phosphates must be used on heavy land: no loss need be feared, any unused material being kept safely in the soil for the next crop. A small nitrogenous top dressing is desirable only if the plant stands still too long in spring, and runs the risk of attacks from beetles, etc.

A suitable dressing is:

> 10 loads of farmyard manure, 2 to 4 cwts superphosphate.

Cabbages, sprouts, broccoli, etc. These crops require dung almost more than any other, and in favourable situations they respond also to top dressings of artificials. Those recommended for mangolds may be used, but the quantity of nitrate of soda may be increased according to the value of the crops up to as much as 10 cwts per acre in extreme cases.

Rape and other fodder crops to be fed off by sheep. Two rules are important:

> Phosphates increase the feeding value.
> Nitrogen increases the bulk.

Suitable dressings are:

4 to 6 cwts superphosphate or basic slag, 1 to 2 cwts nitrate of soda or sulphate of ammonia.

For any of the above crops seaweed should be used to supplement the dung if it can possibly be obtained.

CEREALS.

Wheat.

Wheat is generally grown (*a*) after potatoes or roots drawn off, (*b*) after seeds grazed, or dressed with dung. It is often followed by barley, but in present circumstances farmers ought to see whether it cannot be taken a second time in place of part of the barley. The necessary conditions for two successive crops are given later.

Wheat is perhaps next to grass the least difficult crop a farmer can grow at the present time for it can usually do very well without dung or potash manures. For this reason dung should not be used unless the requirements of the potatoes and root crops have been fully satisfied. The rule breaks down, however, in dry districts; in parts of Norfolk, for instance, dung is almost indispensable for the wheat crop.

The two fertilisers to which wheat responds most are nitrogen compounds and phosphates.

Nitrogen compounds. Farmyard manure has usually been applied to the crop preceding wheat and sufficient material remains in the soil for a grain crop. But under war conditions it is desirable to increase the stocks of available nitrogen and this can most conveniently be done by top dressings of nitrate of soda or sulphate of ammonia in spring. Such dressings are particularly necessary:

(*a*) When the winter rainfall has been heavy and has washed out the reserves of nitrate from the soil.

(*b*) When the crop is standing still in spring and falling a victim to an attack of some pest such as wireworm.

In either case a little nitrate of soda will help the crop along. The great advantage of nitrate of soda is that it begins to act at

once, so that the farmer need not apply it until he is sure it is absolutely necessary.

(*c*) For wheat following wheat or oats. This is sometimes considered bad husbandry and was indeed forbidden in many old leases. But the introduction of artificial fertilisers has altered the case and if the land is kept properly clean it can be made to carry an indefinite number of wheat crops without coming to grief; the Broadbalk field, for example, is now carrying its seventy-second crop and looking very well.

This fact has met with legal recognition, and the farmer may grow corn crops as often as he likes (and indeed any other crop) notwithstanding any local custom or clause in his agreement, provided he puts back into the land the manurial equivalent of what he removes[1]: these quantities are given later (p. 46).

Phosphates. If an ample dressing of phosphate has been given to the preceding crop there will probably be little need for more for the wheat. Seeds, however, do not usually receive much phosphate, and the succeeding wheat may require it. Phosphates promote root development through the winter, and hasten ripening, and therefore are useful in districts where the harvest is apt to come late: they are also wanted for spring wheat. Superphosphate is usually best, slag or bone meal also serve; whichever is chosen should be applied in the autumn.

Potash is only rarely needed. In the Wiltshire experiments[2] it was found necessary, and on thin land it is helpful. In these cases lack of potash may be remedied by a dressing of dung and a top dressing of salt in the spring.

Wheat responds very well to kindly treatment. Under the ordinary four course shift the Rothamsted soil gives about 27 bushels per acre; with suitable artificials this is forced up to 40 bushels. The soil is not peculiar: it resembles considerable areas of land in the country. Low yields may be due to the soil or the climate: to a great extent the soil deficiencies can be overcome but the climate cannot. There is therefore a limit set by the natural conditions, beyond which the yield will not increase except by growing the wheat as a garden plant.

[1] By the Agricultural Holdings Act of 1906, Section 3 (1).

[2] *Wilts Reports*, 1908–9.

There are two common cases:

(1) 40 *bushel crops possible*, 30 *bushels or less usual.* There is a great amount of land of this description, e.g. much of the boulder clay of the Midlands and the flinty clay of the Home Counties. In days gone by it was accounted good wheat land, and the old men still tell of wheat crops growing so vigorously in the spring that they had to be eaten down by sheep because they threatened to be too rank, but nevertheless coming out well in the end. Dung, of course, was liberally supplied in autumn and often top dressings of soot in spring.

When the bad times came the pride in wheat growing was lost. For years wheat had to do without farmyard manure and it only got a spring dressing when it was looking really bad. This is all changed by the war. Wheat is so high in price that it can now go back to the place it had in the farming of the 'sixties. But the methods have obviously to change: farmyard manure is wanted for potatoes and roots, and soot cannot always be had. Their place must be taken by a dressing of artificials.

In ordinary circumstances the increase produced by a spring dressing may cost more than it is worth, but at the present time the risk may well be taken. The Rothamsted results are as follows:

Influence of increased dressings of Nitrogenous Manures on Yield of Wheat, Broadbalk Field; Average of 61 *years*—1852–1912.

	Grain bushels	Increase per 200 lbs ammonium salts bushels	Straw cwts	Increase per 200 lbs ammonium salts cwts
Mineral manure alone	14·5	—	12·1	—
Mineral manure + 200 lbs ammonium salts	23·2	8·7	21·4	9·3
Mineral manure + 400 lbs ammonium salts	32·1	8·9	32·9	11·5
Mineral manure + 600 lbs ammonium salts	36·6	4·5	41·1	8·2

Cost and Value of Increased Produce.

(*a*) Ordinary circumstances. Wheat at 30*s*. Straw at 20*s*.

	Single dressing £ *s.* *d.*	Double dressing £ *s.* *d.*	Treble dressing £ *s.* *d.*
Value of increase	2 1 11	4 6 10	5 11 10
Cost of extra manure	1 6 0	2 12 0	3 18 0
Profit on extra manure ...	0 15 11	1 14 10	1 13 10

(*b*) Special circumstances. Wheat at 50*s*. Straw at 20*s*.

	Single dressing	Double dressing	Treble dressing
	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
Value of increase	3 3 8	6 10 10	8 7 1
Cost of extra manure	1 6 0	2 12 0	3 18 0
Profit on extra manure ...	1 17 8	3 18 10	4 9 1

The additional cost of harvesting the larger crops is not included, and has still to be deducted from the profits.

On the other Broadbalk plots it is shown that a double dressing of nitrate of soda gives better results than a single dressing. The figures are:

Single dressing ... 13·5 bushels increase,
Double dressing ... 4·2 bushels additional increase.

The dressings contain the same amount of nitrogen as 200 and 400 lbs respectively of sulphate of ammonia: thus on the basis of equal nitrogen content the nitrate of soda gives the better return. Roughly speaking each additional hundredweight of nitrate of soda or sulphate of ammonia up to 4 cwts gives an additional sack of wheat per acre. At present prices this is profitable (see Fig. 8, p. 24).

The following dressings may be suggested:

Lighter soils.

Autumn or Spring. 2 cwts superphosphate unless the preceding crop received 3 or 4 cwts.

Spring. 1 to 2 cwts nitrate of soda or sulphate of ammonia. 2 cwts of salt, where kainit is known to be beneficial.

In districts of low rainfall, however, these dressings may not prove remunerative. Farmyard manure will probably be the best under these circumstances.

Heavier soils.

Autumn. 2 or 4 cwts superphosphate or basic slag, especially if the winter is usually wet and the plant stands still, or if the weather at harvest time is uncertain. Superphosphate could, however, go on as a spring dressing.

As a rule the wetter the climate and the heavier the soil, the more pronounced becomes the need for phosphates.

Spring. $1\frac{1}{2}$ to 3 cwts nitrate of soda or sulphate of ammonia or, if bad tilth is feared, 30 bushels of soot. The large dressings must be given in two applications, and not all at once.

(2) 40 *to* 50 *bushels normally produced.* On this sort of land no general advice can be given. On land of the brick earth type that produces large heads well set with corn and borne on stiff straw it may be safe to try and squeeze out a little more produce by somewhat increasing the usual dressing, or by a spring dressing of say about 1 cwt sulphate of ammonia or nitrate of soda. On lighter land heavily sheeped, where the wheat already tends to lodge badly, it would be too risky to attempt this. With the prospect of short labour at harvest time one would not like to contemplate the possibility of laid crops.

If a second wheat crop is being taken, contrary to the terms of the lease, but under the provisions of the Agricultural Holdings Act of 1906, the following equivalent manurial ingredients per acre must be returned to the soil:

		Phosphate		
	Nitrogen	as Phosphoric Acid	as Tricalcic Phosphate	Potash
Grain only sold:				
30 bushel crop	34	14	31	9
40 „ „	46	19	42	12
Grain and straw sold:				
30 bushel crop	50	21	46	29
40 „ „	67	28	62	39

The spring dressings suggested above would supply all the phosphate and much of the nitrogen required, and sufficient potash would probably be contained in the dung applied to the following root crop. In case of dispute, however, it would be well to consult the County Adviser.

The seed should always be pickled before sowing to prevent smut. Either of the following mixtures will suffice for 10 bushels of seed: 1 pint of the ordinary 40 per cent. formaldehyde in 9 gallons of water, or $2\frac{1}{2}$ lbs of sulphate of copper (bluestone) powdered up and dissolved in $2\frac{1}{2}$ gallons of water. Care must be taken that the seed is treated uniformly, as any that gets too great a dose may fail to germinate.

Oats.

Oats are, like wheat, a national necessity at the present time and must therefore be liberally treated. Fortunately oats have been the subject of numerous experiments and in each locality where they form an important crop a suitable dressing has been worked out. This is usually 2 cwts kainit, 2–3 cwts basic slag or superphosphate, worked in with the seed: 1–1½ cwts nitrate of soda or sulphate of ammonia applied later.

Where kainit is known to be essential it would be well to use dung, or if this cannot be spared, salt. It has sometimes proved advantageous to put on part of the nitrogen as sulphate of ammonia (1½ cwts per acre) at the time of sowing, and the rest as a top dressing of nitrate of soda (1 cwt per acre) later on.

The standard dressing worked out on the basis of the West of Scotland College experiments is: 2–3 cwts superphosphate, 2–3 cwts kainit, ⅔ to 1 cwt sulphate of ammonia, all harrowed in at the time of seeding. Practically the same results are obtained by replacing the sulphate of ammonia with a top dressing of nitrate of soda or nitrate of lime after the crop is well up. Basic slag proved suitable in place of superphosphate for winter oats but not for spring oats, except on very moist soils such as moss land.

Barley.

From our special point of view it is unnecessary to say much about barley except that some of it should be displaced by wheat. Where grown after roots fed off it is often improved by 2 cwts superphosphate. Suitable nitrogenous dressings are: 1 cwt sulphate of ammonia or nitrate of soda, or 3 cwts rape cake. There is no substantial evidence for supposing that nitrate of soda in this amount injures the quality: season is far more potent than manuring in this direction. In the Yorkshire experiments 1 cwt sulphate of ammonia gave an additional 5 bushels of grain, while the phosphate gave an additional 2 bushels[1].

[1] *Leeds Bull.* No. 75, p. 12, 1909.

The Seeds.

The seeds course forms the most convenient place for the applications of lime or limestone, and 10 cwts per acre of the former or 1 ton of the latter should be put on in autumn or winter to help the clover. 3 cwts basic slag may also go on for the same purpose.

If a mixture of rye grass and clover has been sown but the clover is looking bad in spring and is obviously not going to grow up, a dressing of nitrate of soda should be given so as to make the best of the grass.

Peas and Beans.

These crops must have lime. Basic slag (6 cwts per acre) has proved advantageous for beans in the Durham experiments. They would do with potash also if they could get it: failing that, however, they may be supplied with 10 to 12 tons of dung.

Distribution of manure throughout the rotation.

Numerous experiments have shown that it is not good practice to put all the manure on to one crop, and give nothing to the rest of the rotation. The dung may go to the most important crop—roots in cattle-feeding districts, potatoes in other cases, roots and wheat in the Eastern Counties—but the other crops must have artificials.

It may not be practicable to give dressings to every crop in the rotation, nor is it always necessary; the best arrangement can only be decided on the spot, after taking everything into consideration. Under present circumstances it is better to err on the liberal side and give too much manure, than to get small crops. The extra labour involved in giving spring dressings is only small, and the return may be very considerable.

CHAPTER V

THE MANURING OF GRASS LAND

There is much discussion at the present time as to whether or not farmers should plough up their medium and poor grass land. Much of it brings in very little, and would produce a greater amount of food for man and beast in arable cultivation than it does now. These facts are not in dispute: the whole question is one of practicability. A grass farmer is not an arable farmer, and in any case if a man is short of labour he may feel very reluctant to increase his area under the plough. The question is one for each to decide for himself: the only general advice one can give is to break up medium grass land if the state of the soil and the labour market affords sufficient prospect of carrying through a series of crops.

Even with the best intentions, however, farmers will still retain a large amount of grass. In view of the imperative necessity of increasing the food production of the country it is essential that this grass should give the greatest return possible, and to this end it must be properly manured. This is by no means an easy matter. Grass is a permanent crop and carries mistakes in management for a long time: you cannot wipe the slate as with an arable crop, and start afresh at the beginning of the next season. Further, on grass land there are at least four different crops: top grasses, bottom grasses, clovers, and weeds; these are all competing with one another, and a scheme of manuring that looks very good may turn out unsatisfactory, because it interferes in this competition in some unexpected way.

Several considerations have to be borne in mind in drawing up a scheme of manuring for grass land. In the first instance grass, like any other crop, must have proper surroundings; it

must have sufficient depth of soil, enough, but not too much, water, and sufficient lime to ensure that the soil is not sour. Further, it wants some cultivation: rolling, harrowing, etc. It will tolerate more neglect than other crops, and usually get it; but it also responds very well to good treatment. The grass land must, therefore, be examined carefully to see if the conditions are favourable to growth, and, if not, how they can be improved. Mole draining and cleaning out water-courses may be very helpful, and liming and suitable manuring may do much. But it is not advisable to spend too much on manuring grass land unless there is some reasonable likelihood of effecting sufficient improvement to pay the cost. Fortunately large areas of grass now very poor can be considerably improved with profit to the farmer and benefit to the country.

The first thing to be done is to decide exactly what the grass land is to be—whether pasture for grazing, or meadow to be laid in for hay. It cannot be both, and the best results are only attained by making a plan, and sticking to it. There may be something to be said for grazing the aftermath or for occasionally laying in a poor or medium pasture for hay (though a good pasture should never be treated in this way), but as a general rule each field should be kept to one purpose only.

Hay Land.

Hay land may be satisfactorily manured either with dung or with artificials, and the choice must be dictated by circumstances.

Where dung is available. Where plenty of dung is available it may advantageously be applied to the hay land at the rate of 10 or 12 tons per acre in autumn. It may be given as frequently as every year with good results (see p. 54), but usually there is only sufficient for dressings in every fourth season. In this case something should be given in the intervening years, and on the whole the most satisfactory fertiliser is basic slag, as this supplies the constituent of which dung contains least, viz. phosphate, and also lime. The improvement obtained is shown in the following experiment made by the Cambridge Agricultural Department at Shenley, Herts[1].

[1] *Cambridge Reports,* Guide to Experiments, 1905, p. 66.

Manurial dressings, 1899 and 1901	Manurial dressings, 1900 and 1902	Average yield of hay, 6 years, 1899–1904
		cwts per acre
8 tons dung	No manure	41
8 tons dung	4 cwts basic slag	45
4 cwts basic slag	No manure	38
No manure	No manure	21

Dung not available, artificials to be used. Usually the difficulty on the farm is to get enough dung, and fortunately grass land can do perfectly well without it, so that the whole supply can, if necessary, be used for roots or other crops. Artificials also produce very definite effects on the herbage, and under skilful management the farmer can succeed in altering it to a considerable extent to suit his own requirements. The general rule is that nitrogenous manures give bulk, while phosphates and potash give quality, and by a judicious combination the farmer may to some extent achieve both.

The most suitable nitrogenous manures for producing bulk of herbage are nitrate of soda, sulphate of ammonia, and the new fertilisers—nitrolim and nitrate of lime. Many farmers have obtained hay for a number of years simply by applying $\frac{3}{4}$ to $1\frac{1}{2}$ cwts of nitrate of soda per acre and nothing else to the land.

But this scheme cannot be recommended because it causes serious deterioration of the herbage. At Rothamsted one of the plots has long received $2\frac{1}{2}$ cwts of nitrate of soda per acre each year: an average yield of 34 cwts of hay has been maintained, but there has been a marked falling off in the quality; the clover has decreased, and the weeds have increased so much that they now make up more than 30 per cent. of the whole (Fig. 9).

Sulphate of ammonia used by itself produces equally undesirable results. On the average the yield is practically the same as with nitrate of soda—36 cwts per acre—though it has not kept up so well of late years; clover has entirely disappeared, and the grass is mainly sheep's fescue.

When nitrate alone is used in practice the falling off in quality shows itself in the great variety of herbage and the number of flowers; ox-eyed daisy, scabious, bird's-foot trefoil, hawk-bit, and

many others appearing along with the delicate-looking quaking-grass.

The cause of the deterioration lies in the fact that neither nitrate of soda nor sulphate of ammonia furnishes a complete food for the plant; phosphates are needed also, and on some soils, usually the lighter ones, potash salts as well.

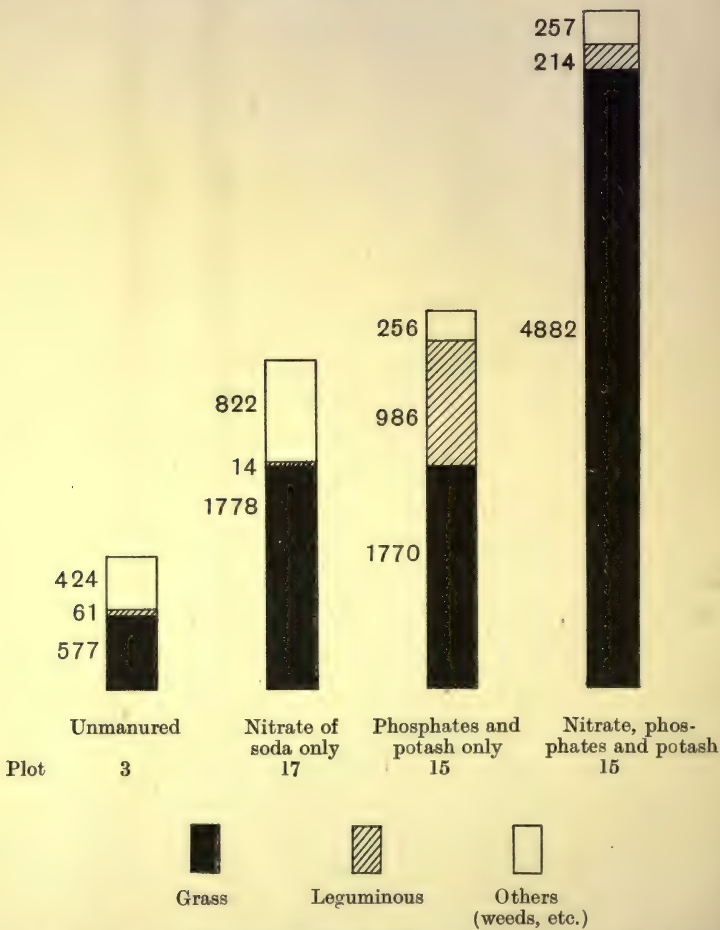


Fig. 9. Effect of artificial manures on the yield and composition of hay. Rothamsted.

(The figures give the actual weights in lbs per acre obtained in 1914.)

When the complete dressing of artificials is used instead of nitrate or ammonium salts alone, a higher yield of considerably better quality is obtained: the average results at Rothamsted are:

	Plot	Yield of hay, cwts per acre, average of 57 years, 1856–1912	Percentage composition of hay, samples taken during 1856–1912: Grasses	Clovers, etc. (Leguminosæ)	Others (weeds, etc.)
Nitrate of soda + phosphates and potash, etc.	16	46·3	82·9	5·4	11·7
Nitrate of soda alone ...	17	33·7	71·0	1·3	27·7

The clovers, etc., do better, and so do the grasses, consequently the weeds become crowded out to a greater extent.

This is further demonstrated in the Cambridge experiments at the University farm for the seasons 1901 and 1902, when the following results were obtained[1]:

	Cwts hay per acre: 1901	1902	Increase in 2 years over unmanured
Unmanured	22½	26¼	—
Sulphate of ammonia alone, 2¼ cwts per acre	32½	48	34½
Sulphate of ammonia + 10 cwts of basic slag	46½	63¾	64¼
Slag alone	32	43	29

The fact that a complete artificial manure is well suited to grass land laid in for hay is shown by the fact that the hay steadily improves as time goes on. Thus at Rothamsted in 1914, a dry year very unfavourable for hay, the results were:

	Plot	Yield of hay, cwts per acre	Percentage composition of hay: Grasses	Clovers, etc. (Leguminosæ)	Others (weeds, etc.)
Nitrate of soda + phosphates and potash, etc.	16	37·5	74·4	15·6	8·3
Nitrate of soda alone ...	17	23·3	68·4	0·6	30·2

[1] *Cambridge Dept. of Agric. Fifth Annual Report*, 1903, p. 29.

Another instance is furnished by the Garforth experiments[1] over the 12 year period, 1899–1910. A complete mixture of artificials applied every year gave the highest percentage of good grass, and the lowest percentage of weeds. Cocksfoot and golden oat were strongly encouraged, while bent and sorrel were greatly reduced. The omission of potash only slightly brought down the yield, but affected the quality of the herbage to a greater extent, reducing the proportion of grass, and increasing that of weeds, especially of sorrel:

	Plot	Yield of hay, cwts per acre	Composition of herbage			
			Grasses		Leguminosæ	Others (weeds, etc.)
			Good	Inferior		
Unmanured	1	29½	17·8	59·1	Nil	18·3
10 tons dung annually	2	52½	43·3	14·3	Nil	36·8
Complete artificials*	7	42¾	69·6	15·5	0·3	10·8
Nitrate and superphosphate only ...	9	40½	56·6	12·7	Nil	24·5

* 1½ cwts $NaNO_3$, 2 cwts superphosphate, 3 cwts kainit per acre.

Dung encouraged the good grasses, especially foxtail and cocksfoot, and repressed bent, but it also encouraged soft brome—a poor grass—and very considerably increased the proportion of weeds.

The Cockle Park experiments[2] led to the same results. Nitrogenous manures increased the crop, but caused deterioration in the herbage. When basic slag was supplied in addition there was a larger and much more profitable crop. None of the manures tested, however, were as effective as the combination of dung and artificials[3], or as profitable as dung. Thus, on the Palace Leas Field the average yields of hay in cwts per acre for the 18 years—1897 to 1914—and the live weight gains per week in sheep fed on equal weights of the hay during the period November, 1905, to January, 1906, were:

[1] *Leeds Bull.* No. 85, p. 5, 1910.

[2] *Cockle Park Bull.* No. 22, 1915.

[3] The dressings were 150 lbs sulphate of ammonia, 300 lbs slag (or, in some of the earlier years, 400 lbs super.), 100 lbs muriate of potash per acre.

	Unmanured Plot 6	Sulphate of ammonia alone Plot 7	Sulphate of ammonia and slag Plot 10	Slag and potash Plot 12	Dung (8 tons) and artificials ($2\frac{1}{2}$ cwts) Plot 1	Dung (8 tons) alone Plot 2
eld of hay, cwts per acre	$19\frac{1}{4}$	24	31	$26\frac{1}{4}$	42	39
ve weight gains in sheep, lbs per week	1·78	—	—	2·26	1·65	2·04
rerage annual gain or loss over unmanured... ...	—	– 5*s*. 6*d*.*	5*s*. 5*d*.	2*s*. 11*d*.	1*d*.	9*s*. 5*d*.
rerage annual gain or loss over unmanured when quality is taken into account	—	– 11*s*. 7*d*.	9*s*. 3*d*.	19*s*. 11*d*.	– 8*s*. 5*d*.	23*s*.

* Loss of 5*s*. 6*d*.

When the complete manure is used it is safe to increase the dressing of nitrate of soda or sulphate of ammonia, and as a general rule the more nitrogenous manure is used the bigger the crop. Whether the increase is profitable depends of course on prices. There is some deterioration in quality: the tall growing grasses flourish so much that they crowd out the weeds. Thus, at Rothamsted the results were:

	Yield of hay, cwts per acre Average 57 years	Percentage composition of hay		
		Grasses	Clovers, etc. (Leguminosæ)	Others (weeds, etc.)
Nitrate of soda + phosphates and potash	46·3	82·9	5·4	11·7
Double dose of nitrate of soda + phosphates and potash, etc.	56·9	88·8	3·7	7·5
Equivalent dressings of sulphate of ammonia + phosphates and potash, etc.	54·3	91·2	1·3	7·5

Similar results were obtained in the Yorkshire experiments[1]:

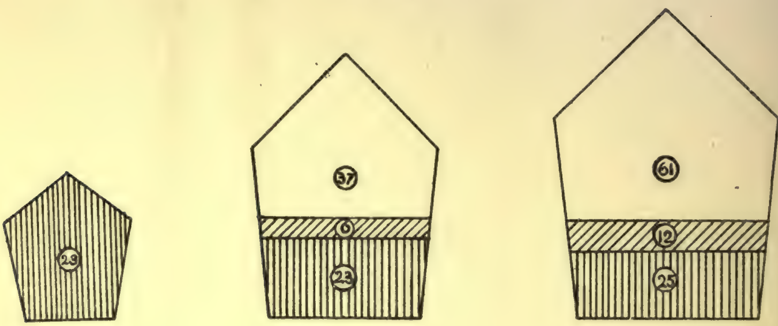
Manurial dressings per acre	Average yield of hay, 1899 and 1900 cwts per acre
Unmanured	21·5
2 cwts superphosphate, 3 cwts kainit, and no nitrate of soda	25·5
" " " " 1 cwt " "	32·5
" " " " $1\frac{1}{2}$ cwts " "	35·0
" " " " 2 " " "	37·8

[1] *Leeds Dept. of Agric. Rep. for* 1900, No. 14, Table VI.

The Lancashire experiments also gave similar results. But when the amounts of kainit and of superphosphate were increased there were no such increases in the yield of hay. It makes very little difference to the yield whether sulphate of ammonia or nitrate of soda is used, but such advantage as there is lies in favour of the nitrate of soda.

Poor hay land.

In some cases, however, the herbage is so poor that there would be no object in trying to get large crops, and an improvement must first be effected. This can usually be done on boulder clays by a dressing of basic slag. 10 cwts should be



Unmanured **5 cwts basic slag per acre** **10 cwts basic slag per acre**

Fig. 10. Effect of slag on grass land laid in for hay at Saxmundham (from the 1903 Report by T. H. Middleton). The lower part represents the yield without manure, the central portion the amount required to pay for the cost of the manure, and the top portion the profit.

given in autumn, and nothing else for two or three years: meanwhile careful watch should be kept on the clovers. If after this period the herbage shows improvement, 1 cwt of nitrate of soda may be applied annually for two or three years, to be followed by a dressing of basic slag as before. Fig. 10 shows the effect produced at Saxmundham.

Where slag alone does not improve the herbage the case is often difficult. No general rules can be given; each case must be decided by itself.

Meadow foxtail (*Alopecurus pratensis*) Cocksfoot (*Dactylis glomerata*) Meadow fescue (*Festuca pratensis*)

Fig. 11. Good hay plants. If the herbage is mainly like this, and in addition there is a good deal of clover, it is proof that the conditions are satisfactory.

Yorkshire fog (*Holcus lanatus*) | Downy oat (*Avena pubescens*) | Quaking-grass (*Briza media*)

Fig. 12. Poor hay plants. Signs that something is wrong. Yorkshire fog indicates wetness or sourness, and Downy oat and Quaking-grass indicate poverty.

What is the best phosphate to use? There are three to be had: basic slag, superphosphate, and bone meal or bone flour. Basic slag is the cheapest and it also supplies lime, which the other fertilisers do not: it has proved very useful on clay soils and wherever the rainfall is fairly high—28 inches or more; in the Irish experiments it came out equal to superphosphate (p. 28); it has been less successful, however, on lighter soils and under drier conditions. Bone flour is rather dearer, but it has given good results in the drier conditions where basic slag has not worked well; it has succeeded on alluvial meadows in parts of Bedfordshire (where the rainfall is 28 inches). Superphosphate is the dearest but the most soluble, and, like bone meal, has given good results in regions of low rainfall; it is useful on the lighter soils. In the Aberdeen experiments[1] it gave the most profitable results in the year of application, but not afterwards.

The use of potash. If potash salts were available in quantity the proper course would be to apply them to the lighter soils, but as they are not some other plan must be used instead.

There are three ways round the difficulty.

1. Liquid manure may be applied at the rate of about 2000 gallons per acre. The lighter lands will benefit most from this treatment.

2. Salt may be applied at the rate of 3 to 5 cwts per acre. This is unnecessary on heavy land, and is only wanted on light soils.

3. Lime, chalk or limestone may be applied. Both light and heavy soils may benefit from this.

Lime, limestone or chalk. One of the most important requirements of grass land is lime or limestone, and a dressing should be given every four years unless it is definitely known to be unnecessary or uneconomical. There are several signs to show when lime is wanted:

Very dark green patches begin to appear.
Tufts of Yorkshire fog show up.
Clover begins to fail.
Sorrel starts spreading.

The presence of sorrel in grass land is not definite proof that

[1] *Aberdeen Bull.* No. 5, 1906.

lime is wanted: sorrel will tolerate lime quite well. But it can do without lime better than many other plants, and when it begins to spread at the expense of others it indicates that lime is beginning to run short.

So far as the plant is concerned it does not very much matter in what form the lime is added: the farmer can therefore suit his own convenience (see p. 3).

One ton of ground lime or 2 to 4 tons of ground limestone are useful dressings. Chalk is good where it can be got cheaply, but if it is in big lumps it distributes so badly that large quantities —40 loads or more—are needed.

General recommendations for hay. To get bulk use 10 tons of dung in autumn every third year, if it can be spared. When this is not done use 1 to 2 cwts of nitrate of soda or sulphate of ammonia in March.

To improve the quality and give a little more bulk add to this 3 to 5 cwts of basic slag or superphosphate; slag on heavy soils, or wet places, or where the rainfall exceeds 26 inches a year; superphosphate under drier conditions, or where prices are higher than usual so that you want to get as much as you can in the first year. If the land scorches in summer, add to the other artificials 3 cwts of salt or of kainit if it can be got.

To sweeten the herbage, apply 10 cwts of lime, or 1 ton of ground limestone, as early as possible.

Pasture Land.

The main factor determining the success of pasture land is the management: the land requires proper grazing even more than proper manuring, and unless it is well grazed money spent on manures does not give its full return.

Assuming the management to have been good, and the land well grazed by stock receiving cake, there is no need to add any manure except occasional lime and phosphates. If nothing has been added for a number of years it will be well to try whether better results could not be obtained from dressings of superphosphate or of basic slag: many cases are on record where these have improved the feeding value of the herbage, even on good pastures.

Dog's tail (*Cynosurus cristatus*) Rough-stalked meadow-grass (*Poa trivialis*) Rye-grass (*Lolium perenne*)

Fig. 13. Good pasture plants, showing that the conditions are satisfactory.

Bird's-foot trefoil (*Lotus corniculatus*)

Rush (*Juncus communis*)

Bent (*Agrostis vulgaris*)

Hawkbit (*Leontodon hispidus*)

Fig. 14. Poor pasture plants, indicating that the conditions are not good. Rush indicates wetness, Bent indicates unsuitability for root development, Hawkbit and Trefoil show poverty.

Where the herbage is not satisfactory it should, if possible, be improved. If there are many rushes about some attempt should be made to drain off the excess of water by improving the water-courses, by mole draining, or other methods. Big tufts of coarse herbage must be removed by cattle, young colts, or the scythe. But it is no use trying to improve matters by adding dung or feeding cake, this indeed may only make things worse.

Usually poor pasture land is deficient in two constituents: phosphates and lime; and, until these are added, nothing else will effect any improvement. Some hill pastures lack potash as well, but these are not usually very valuable. The need for lime is particularly marked on heavy soils and in wet regions, and it is aggravated by the circumstances that the soil is perpetually receiving the animals' excretions, and also being trodden by them. On the other hand the need for nitrogenous manures is not great: as the pastures improve they should become well covered with clover, which adds considerably to the stores of nitrogen in the soil: further, any cake or meal fed to the animals at grass increases the nitrogen supply by increasing the richness of the excretions. Cases are on record, however, where a dressing of nitrogenous manure has proved useful on an improved pasture by causing the grass to start growing early.

Roughly speaking there are four sorts of poor pasture in the country:

1. On *poor clay*, covered with small bare patches, and carrying bent grass which gives it a peculiar russet brown appearance in autumn. This has formed the subject of a good deal of experiment all over England and Wales, and especially in the northern counties. It has been shown that cake and nitrogenous manures produce little, if any, permanent benefit, but a liberal dressing of basic slag causes marked improvement, fostering the development of white clover. Usually 10 cwts of slag is all that is wanted to convert failure into success. In some few cases it has happened that clover was absent altogether: it is then necessary to harrow in some wild white clover seed. The best known instance is at Cockle Park, Northumberland, a poor pasture lying on a subsoil of poor yellow boulder clay, which had never been worth more than 10*s*. per acre, and in 1897 when the experiment began was said to be

worth only about 2*s*. 6*d*. per acre. Part of Tree Field then received 10 cwts per acre of basic slag and nothing more; it was grazed with sheep which received no cake or meal, and the increase in live weight was noted. On another part of the land the sheep received decorticated cotton cake for the first year, but no fertiliser was applied to the land: in 1903 and 1904, cake was also fed. After the experiment had continued for 9 years, the first plot received a further dressing of slag (10 cwts per acre). The live weight increases in the sheep, reckoned as lbs per acre per annum, were as follows[1]:

	No cake No manure Plot 6	Decorticated cake* No manure Plot 1	No cake Basic slag (10 cwts in 1897 and 1905) Plot 3
1st 9 years, 1897–1905 ...	37	106·7	117
Increase due to manuring	—	69·5	80
2nd 6 years, 1906–1911 ...	23	42·5	117
Increase due to manuring	—	19·5	94

* 597 lbs cake per acre in 1897–8, in 1903 and in 1904.

The plots are shown in Fig. 15.

The cake gave good results in the years when it was fed, but not afterwards. Similar but larger increases in live weight were obtained in the Hanging Leaves Fields where cattle and sheep have grazed together, the mixing of animals being good for the pasture; considerable stress is laid on this.

The experiment was repeated at Cransley, in Northamptonshire, on a poor wet boulder clay. Over a three year period one dressing of 10 cwts of basic slag gave just as much live weight increase in the sheep set to graze the pasture as 1 lb of decorticated cotton cake per head per day for the first two years—13½ cwts per acre in all. (Fig. 16.) And, moreover, the improvement made by slag lasted, while that made by cake did not. Similar results were obtained at Hatley in Cambridgeshire, and at Yeldham in Essex[2].

After the improvement by slag it is essential to graze the land well. Cake can now be fed if desired, and further dressings of slag periodically given.

[1] *Cockle Park Bull.* No. 7, 1906, and No. 19, 1913.

[2] See *Cambridge Reports*, Guide to Experiments, 1905.

Plot 6. Unmanured.

Plot 3. 10 cwts basic slag.

Fig. 15. Cockle Park grazing experiments (Tree Field).
(Photos kindly supplied by Prof. D. A. Gilchrist.)

It is not to be supposed that these sorts of results are obtained on all clay pastures. The great feature of slag is that it encourages the growth of white clover where other conditions are favourable; it has a good opportunity for doing this where bare patches exist

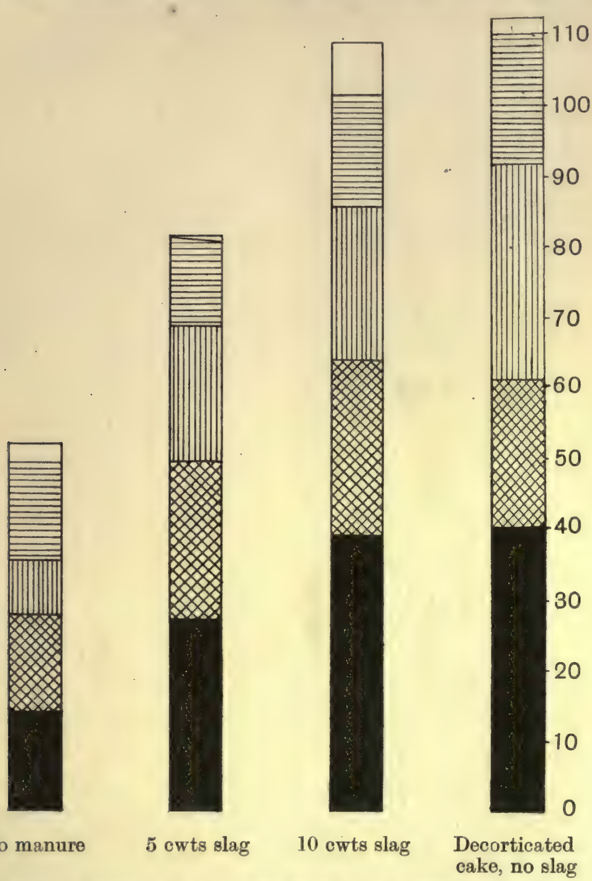


Fig. 16. Average increase in live weight of sheep receiving no cake on land dressed with basic slag, in comparison with sheep receiving cake on land without manure. The columns represent total gains in lbs per acre while the sections represent the gains per month, the bottom being the first month.

on which the clover can develop. Where the pasture is well covered with other vegetation the chance of improvement is less, but even here the additional supply of phosphate may increase the nutritive value of the herbage.

Marked improvement was obtained at the Midland Agricultural College by the use of superphosphate (4 cwts high grade) and sulphate of potash ($1\frac{1}{2}$ cwts) on a poor heavy clay on the Keuper Marl formation[1]. The plots were grazed with milch cows and the yields in lbs of milk per acre for the four seasons, 1909–1912, were:

Season	Unmanured	Super. and potash	Difference due to manure in lbs per acre	Difference due to manure in gallons per acre	Profit on the treatment £	s.	d.
1909	1383	2255	872	84	0	13	0
1910	1672	2558	886	86	2	3	0
1911	1397	2230	833	81	2	0	6
1912	2185	3415	1230	119	2	19	6
				Total for 4 years ...	7	16	0

Nothing was applied after the first dressing in 1909.

2. *Down land.* On the South Down pastures west of the Sussex Ouse, where the rainfall is considerable, marked improvement has resulted from the use of basic slag.

3. *Poor hill pastures.* It is difficult to make any general rule about this. Improvement has been effected by the use of basic slag[2], and also by lime; in other cases a mixed dressing of basic slag and kainit was necessary, but the results were never as striking as at Cockle Park, and the cost was often more than the return, so that the transaction was not profitable. The margin for improvement is not very great, and each case has to be considered on its merits; all that can be done is to find out from the county agricultural authority what experiments have been made on similar land.

4. *Hot pasture on sand or thin gravel.* These cases are also very difficult, and not many experiments have been made on them. The determining factor is usually the underground water supply; if this is satisfactory there is hope for improvement by suitable grazing and manuring. In some cases basic slag has given good results, in others bone meal, and in others again sometimes a dressing of meat meal or fish meal has been best.

Where the underground water supply is inadequate the case

[1] *Midland Agr. Coll. Reports*, 1909–1912. Both plots had previously received 10 cwts lime per acre.

[2] Greig, *Aberdeen Bull.* No. 16, 1910.

is not very hopeful. No generalisation is possible; all that can be done is to ascertain from the County Expert whether similar land elsewhere has been improved in any profitable manner.

The Highland and Agricultural Society's trials are discussed by Wilson in their *Transactions* for 1905 (p. 271), and are finally summed up by Hendrick in the volume for 1911 (p. 290).

Moorland or peaty pasture. On peaty soils in France and the United States the mineral phosphates have proved of great value, and as they are considerably cheaper than basic slag or superphosphate they are worth trying on similar soils in this country. Occasionally potash is greatly needed by these soils, however.

General recommendations for pasture. The great point about pasture land is to graze it properly.

Next, remember that the animals, especially growing or milking stock, are perpetually draining it of lime and of phosphates; make provision, therefore, to return these. Basic slag is a suitable fertiliser on heavy land or in wet districts; superphosphate does well in drier conditions, or where a quick return is desired.

If the quality of the herbage is not good, cake feeding and dressings of dung are not likely to mend matters, and may only make them worse. The proper remedy is a course of artificials.

Poor hill pastures and hot pastures on sand or thin gravel present difficult cases, about which no general rule can be given. The best plan is to apply to the County Adviser, and see what methods have succeeded elsewhere; then try the one that suits your conditions best. But, above all, try and improve the pasture.

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[P. T. O.